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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXXIV.—*On the Physiographic Improbability of Land at the North Pole;* by J. W. Spencer, A.M., Ph.D.

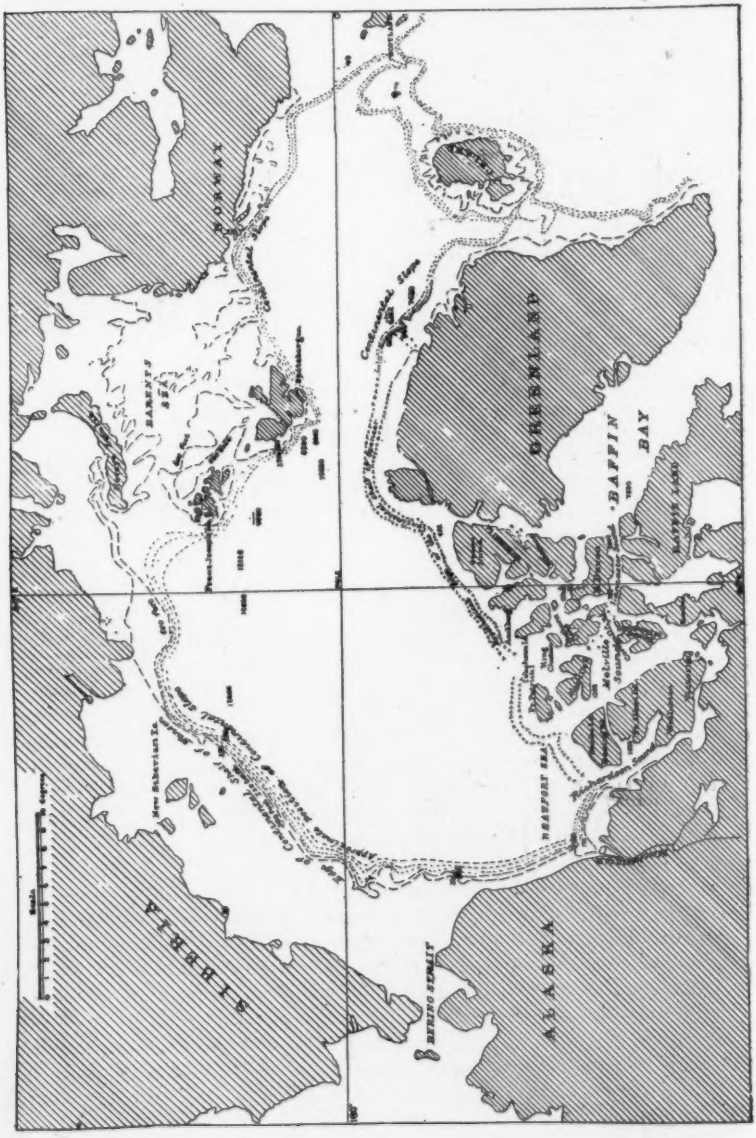
The earlier explorers had little to guide them, but they brought back occasional soundings, which seemed to indicate a shallow Arctic basin. The drift wood suggested that it was a more or less open sea, beneath the ice floes, even though its depth might not be great. Some soundings were of unusual depth, but their importance, not being known, was entirely overlooked. The soundings in the Arctic region were insufficient of themselves to suggest their own explanation, before the character of drowned channels was understood. Indeed, while occasional valleys channeling the submerged border of the continent had been noted by Dana, Lindenkohl, Milne-Edwards, Davidson, Issel, the present writer, Upham, and others, the systematic study of these features really dates back only to 1893–4, resulting in the publication of the "Reconstruction of the Antillean Continent."* This has been the pioneer of many subsequent contributions on submarine valleys and drowned plains. The same features have been studied on the western side of Europe by Prof. Edward Hull,† and in the Arctic region and farther south by Prof. F. Nansen.‡ Accordingly the features of submarine valleys channeling the edge of the Continental mass are now pretty well understood, so that we can interpret even the limited amount of data already obtained in the Arctic region and have some reasonable understanding of the phenomena which they indicate.

I was in northern Norway when the Ziegler expedition sailed, and hearing of their expectation of finding Polar land,

* By the present writer, Bull. Geol. Soc. Am., vol. vi, pp. 103–140, 1894.

† Numerous papers, mostly published in Trans. Victoria Institute, London, 1898–1902.

‡ On Bathymetrical features, Continental Shelves and Oscillations, Christiania, 1904, pp. 232, plates 28.


NORWAY
BARENTS SEA
GREENLAND
BAFFIN BAY
SIBERIA
ALASKA
BERING STRAIT

I felt that disappointment was in store for them; for Dr. Nansen's great discovery of a profound Arctic basin, immediately beyond the border of the continental shelf, precluded the probability of finding land between Franz Joseph Land and the Pole, or indeed along this line for a thousand miles beyond, until approaching the embouchure of the Mackenzie River, although to the left of this line the continental shelf north of Greenland, bearing perhaps an island, might extend far polarward. Nansen had found the Polar basin to reach a depth of 12,000 feet or more. This would have to be crossed by any expedition from the European side and here no portable sounding apparatus could be effective until approaching the American shelf beyond the deep basin itself. But had the undertaking been made from Grant Land, soundings to a depth of 3000 feet or less would have surely revealed the rapidly increasing depth of the slope from the continental shelf to the abyss of the basin, out of which no land could be expected to rise. Thus the character of the Polar district would have been discovered, perhaps without reaching to within some hundreds of miles of the Pole, depending upon whether the shelf extends far north of the known land or not. If the Ziegler expedition were for the purpose of adding to our knowledge, it is to me astounding that the route chosen should have been approved of by the advisers, knowing of the deep sea north of Europe, even without such analysis of the subject as has since been published by Nansen, or is here set forth. If the voyage were only one of adventure to reach an icy Pole without any ostensible scientific object, then I give no opinion as to the route taken. These remarks directed to an actual expedition would equally apply to the proposed one of the Duke of Orleans. They are written in the hope that future Polar explorers will take cognizance of the scientific submarine topography, avoiding useless expeditions and devoting their efforts to extending scientific knowledge.

To define the features around the Arctic basin, I should draw an axis from Cape Bathurst, passing close to Bank's Land, Prince Patrick's Land, the Pole, and on to Franz Joseph Land and Novaya Zemlia, thus dividing it into two unequal lobes. The one on the Siberian side is bounded by low lands, with few islands, all of inconsiderable height in front. The confines of the other lobe have bold features in the mountainous islands of Novaya Zemlia, Franz Joseph Land, Spitzbergen, North Greenland, Grinnell Land, Sverdrup's New Land to Prince Patrick's Land and Bank's Land, which have less abrupt features.

In front of the Siberian plains and north of Bering Straits, Dr. Nansen has shown from his own and other soundings that

the continental shelf has a breadth of 300 or 350 nautical miles (see map). Its outer margin is at a depth of 300 feet, beyond which is the rapid descent of the continental slope. In front of Spitzbergen, and apparently adjacent to Franz Joseph archipelago, the shelf has a breadth of only about 30 miles. Its border recedes and forms an embayment east of Novaya Zemlia. North of the New Siberian Islands, Nansen found that the submergence of the continental slope increased from about 300 feet to 6000 feet in 30 miles. A similar gradient has been found adjacent to Spitzbergen. Soundings in sufficient numbers have been taken to establish the existence of the broad shelf, with a few others suggesting its border, as for instance, where in proceeding outward the sea suddenly deepens from 300 feet to 700–800 feet. Thus defined, Nansen's map shows a direct line in front of Bering Straits to north of Alaska. Here the continent encroaches upon and greatly contracts the shelf,—an important analytical feature. The shelf appears to be reduced to a breadth of perhaps 40 miles. The Arctic basin does not approach Bering Straits, which is only a shallow lateral trough from the basin itself, but ends in Beaumont Sea, between Prince Patrick's Land and Alaska, where the Mackenzie River, after passing through its own broad embayment or delta, extends to a submarine valley discovered, so far, to a depth of over 1140 feet beneath sea level, thus deeply incising the shelf. In the broad channel between Bank's and Baring Lands and the continent, which (unless it is otherwise named, and the charts do not show it) might appropriately be called Richardson Sound, after its explorer (1848), the submarine valley has a depth of 1836 feet, near the head of a branch fjord, at a point 175 miles within the line of the islands.

Lower down the sound are a number of deep soundings, but they do not reach the bottom in the central axis. Beyond, in McClure's Strait, which separates the eastern side of Bank's Land from Melville Island, the fjord attains a depth of 1362 feet and more, at a point 200 miles within the line of the islands. Here we have found the evidence of deep submarine valleys or fjords entering Beaumont Sea from three different directions, and very much deeper than the submergence of the great continental shelf of the Arctic basin. Further proof is not needed to establish the fact that Beaumont Sea is a broad profound valley leading to the Polar basin, though the depth is not known. Also, that the continental shelf is deeply channelled by the valleys. Now, as we have learned from the analysis of the submarine valleys or fjords off Norway and both coasts of America, the border of the continental shelves does not usually exceed a distance of more than from 40 to 100 miles beyond the outer line of the land or islands. Off

Spain and Portugal the shelf is reduced to 6–20 miles. While the Norwegian channel is much longer, yet it hardly forms an exception to the rule, for the edge of the continental shelf, even here, is within the line of the land between Scotland and Norway. Even now we have sufficient data to show that the edge of the lower platform at a depth of 1200 feet (like in Barentz Sea) does not exceed a distance of 60 to 100 miles from land off East Greenland and in Baffin Bay. From my familiarity with the study of continental shelves, the margin of that beyond even the lower part of Prince Patrick's Land should not be expected to extend more than a hundred miles, if indeed so much, with such a deep channel extending far within the line of the islands. Neither the Mecham nor the McClintock expeditions found land beyond the northern side of Prince Patrick's Land. These fjords are in the western side of the archipelago. Four hundred miles farther east (south of the western end of North Devon) in the head of Lancaster Sound we find another fjord with a depth of 780 feet deepening in 150 miles to over 4000 feet at a point 50 miles within the line of the islands, while other soundings show the shelf to attain a breadth of only a few miles in this part of Baffin Bay adjacent to the deep fjord, but elsewhere it reaches to 100 miles. About 160 miles north of Lancaster Sound, in Cardigan Strait, on the Arctic side of the *col* between North Devon and North Kent, the depth of the fjord exceeds 2400 feet. This point is situated about 250 miles within the line of Sverdrup's New Land, showing that here is another deep channel trending to the Arctic basin. Now with even the few soundings before us (and there are many more not cited here) the fjord-like character of the archipelago cannot be questioned. It is a dissected plateau region (much of which is now 2000 or 3000 feet high, subsequently submerged in part—a region fashioned by atmospheric agents whether now above or below sea level. As the depths mentioned are far within the land line, and in the case of one sound a depth of over 4000 feet occurs even 50 miles within the land line, there is every reason to expect similar depths nearer the mouths of the other fjords mentioned. Where the submarine valleys have attained considerable depths within the land line the shelf should be relatively narrow; and judging from the position of Sogne fjord (nearly 4000 feet deep) I should not expect to find the breadth of the shelf exceeding 50 miles in front of Sverdrup's New Land, as much of the region is a weatherworn plateau. One sounding north of Grant Land strengthens this view. At about 30 miles off the land the sounding shows 432 feet, somewhat in excess of the submergence of the Arctic continental shelf wherever known off the Siberian coast. It would seem that the edge is being approached. Nansen has pointed

out the remarkable uniformity of the shelf in the Polar basin. Continental shelves are characteristically narrower in front of bold highlands than where they fringe low plains as on the other side of the Polar basin. Apparently the question of the formation of the continental shelf in one part of the Arctic cannot be separated from the rest of it. No land was discerned beyond Prince Patrick's or from Sverdrup's New Land.

From the absence of land for a hundred miles, from the occurrence of the sea depth at 432 feet thirty miles from land, and from the characteristic of narrow shelves in front of high lands, I suspect that Commander Peary passed the edge of the shelf and was perhaps over the deep basin, as he would have been in front of Spitzbergen. From this consideration and from the feature of limitation of the continental shelves being indicated by the presence of deep fjords as found among the islands of the archipelago, and from the characteristics of the platforms in front of high lands, I am inclined to place a theoretical limit of from 50 to 100 miles as the breadth of the shelf in front of the known islands, without the expectation of finding any great islands farther north. If this approximation, based upon physiographic information of no mean value, be correct, there would still remain a distance of 300 or 350 nautical miles between the edge of the shelf north of Grant Land and the Pole, beneath the ice of which obtains the deep basin. The edge of the shelf, indicating the limit of the insular extension of continental lands, wherever found, precludes the probability of land beyond, rising out of a deep sea basin.

Having found a working hypothesis from the physiographic features, other phenomena in support of the hypothesis based on the submarine topography have been mentioned by Dr. Nansen. Along the course of the Fram, at depths of more than 800–900 meters, colder heavy bottom water was found, above that affected by subterranean heat, but beneath the overlying stratum of warmer water. It must have cooled down somewhere in the unknown Arctic basin, in contact with the cold surface water; and this place of wide extent is somewhere far from the course of the Fram, occupying probably the greater part of the still unknown Polar region. Similar phenomena exist in the Norwegian Sea, where, however, the center of cold has been found. The drift of the ice under the coast of Greenland is much greater than where the ice belt is broader in the Polar sea. These additional phenomena further preclude the idea of Polar land.

I have not touched upon the question of possible land north of Bering Straits. The position is much farther from the Pole than that of the locations considered. Nor has the question of

tides been referred to. This last has been ingeniously discussed by Dr. R. A. Harris.* According to him, the currents set eastward and westward from Bering Straits, which he thinks is caused by land to the north. The tides coming from the east of Greenland (rising two feet) recur near Bennett Island, north of the New Siberian, with the same range. The drift of the Jeannette was accelerated on approaching this locality as if a broad strait were situated here. On the coast of Alaska, the tide is reduced to a few inches, caused, Dr. Harris thinks, by the interference of a large land area. Now Bennett Island is more than 100 miles within the border of the continental shelf. Nansen crossed its edge 200 miles northwest of this point, so there is room for an island of considerable size without the shelf protruding beyond its general outline. Although the outline of the shelf, north of Bering Straits, seems to have been approximated, there may be in front of it a secondary platform, on which remnants of a higher one, surmounted by land, occur with characteristics resembling rather the New Siberian archipelago than Spitzbergen, although this last mass partly rises above a lower platform, as would be the case with part of the hypothetical islands north of Bering Straits. It is only on an extension of the continental shelf that the occurrence of land could be expected, and any great extension of it would disturb the symmetry of its outline, a point which should not be overlooked. If the phenomena described by Dr. Harris really demand a great land mass, physiographically there is no reason why there should not be even a nearly continuous chain of islands from near Bennett Island extending towards Prince Patrick's Land, though it could not occur in front of Beaumont Sea. But I find no ground here for extending land nearer than ten degrees of the Pole. Islands would satisfy the tidal currents off Alaska according to Dr. Harris, though it might not explain the tide rising two feet to Bennett Island. My conclusions agree with those of Sir Clement Markham, quoted by Dr. Harris:—who "does not believe in any land near the Pole, but believes there is land probably in the form of large islands between Prince Patrick's Land and the New Siberian Islands." I should limit their occurrence to a line directly connecting these islands, with no important additions, to the American archipelago, a theory suggested by the enclosed fjords. An island may exist near Simpson cove as suggested by Dr. Harris, perhaps constituting the end of a chain from Bennett Island skirting the edge of the continental shelf.

If I were permitted to plan out an expedition for the purpose of adding to our knowledge of Arctic physiography, it would be somewhat on the following lines, so far as physical

* Nat. Geog. Mag., vol. xv, pp. 255-261, 1904.

conditions would permit. Two expeditions have reached Prince Patrick's Land. Another might enter by Bering Straits, skirt the ice and make close soundings in Beaumont Sea, discover the deeper canyon of Mackenzie River, explore to the bottom Richardson Sound and the channels to Prince Patrick's Land. If the ship could not be drifted past this place, a land and over-ice party with portable sounding apparatus, for depths of 500 fathoms, or if possible a little more, should make the utmost effort to reach a point where the water had either such a depth, or land were found, if the sea continued shallow beyond expectations. A hundred miles have been crossed by Peary; probably so long a journey would not be needed. If the ship could be drifted in the ice north of Prince Patrick's, the sound between this land and Sverdrup's New Land should be explored, for islands or open sea. Else the ship might have to follow the old route through Melville Sound, with an effort to revisit Isachsen Land (one of Sverdrup's New Lands), carrying the ship, or repeating the over-ice sounding expeditions to determine the border of the continental shelf. Such a program should be continued to north of Grant Land, various points of which have been visited, even if the ship could not be worked or drifted in the ice. North of Grant Land, and also Greenland, should be revisited as by Commander Peary, but carrying the sounding apparatus, so that when the edge of the continental shelf shall be reached, the explorer would know when his work was finished and avoid useless adventure. Such an expedition, perhaps requiring several years, should be made to round off Polar explorations. It seems to me to be the only one promising great results, at least of a finishing character. Explorations north of Bering Sea would be farther away, and I have no suggestions to make except to sound well the region traversed, by the ship or sledge party attempting a further voyage.

This little paper is only an application of the study of the deep channels trenching the eastern coastal plains of the continent; which study throws much light upon the subject of the physiography of even the Polar regions. There is also an economic aspect of the question of such submarine physiography, as in the laying of cables, so that they will not swing over the precipices of drowned canyons and consequently collapse. Prof. Davidson has reported ships lost by not being able to drop anchor during storms through being unaware of the adjacent shoal waters, outside of the limits of the drowned channels.

ART. XXXV. —*Bibliography of Submarine Valleys off North America;* by J. W. SPENCER.

Papers on the Submarine Valleys indenting the Continental Shelf off the American Coast and in the West Indies; by J. W. SPENCER.

THE appearance of the "Submarine Great Canyon of the Hudson River" has emphasized the absence of easy reference to the scattered contributions where those interested have not continuously been giving the subject their attention. In this case, it may be expressed in the language of a gentleman, a stranger to the writer, who says that he is "now much interested in this particular subject, but has been unable to get hold of any matter regarding it otherwise than a vague popular sketch here and there which has left him about as much in the dark as though he had read only the title." Some of the papers are not of recent appearance. Others have been published abroad. This condition is perhaps sufficient reason to assemble the list of the papers. The subject is one of equal interest in Europe as here, where there would be a greater difficulty in knowing what had appeared on this side of the Atlantic.

In order to call the attention of the American student to what has been done by Prof. Edward Hull and Prof. Fridtjof Nansen, I have prepared somewhat lengthy summaries of their contributions on this subject, as these are more difficult of access here. The writer's investigations are the slow outgrowth of his studies of the origin of the basins of the Great Lakes, which will not be further referred to here. Otherwise, as bearing on the Atlantic border the investigations began with:

1. "High Continental Elevation preceding the Pleistocene Period;" Bull. Geol. Soc. Am., vol. i, pp. 65–70, 1889; Geol. Mag. Lond., III, vol. vii, 1889. (This contains a description of the submarine valleys of the Gulf of St. Lawrence and of Maine to depths of over 3000 feet. The former is now known to be over 5500 feet.)

2. "Terrestrial Subsidence Southeast of the American Continent" (a preliminary notice of the next paper) with map. Bull. Geol. Soc. Am., vol. v, pp. 19–22, 1893.

3. "Reconstruction of the Antillean Continent" with map. Bull. Geol. Soc. Am., vol. vi, pp. 103–140, 1894–5. (Here is a description of the submarine valleys extending beyond the buried channels of great land rivers, and trenching the continental shelf to abyssmal depths, from Cape Hatteras to the Gulf of Mexico and in the Caribbean Sea. The evidences therefrom indicate great Pliocene and Pleistocene elevations, and the land connection of the two Americas. This is the first constructive paper

on the subject, and together with the discussion of the bearings is the foundation of the subsequent work.) Abstract in Am. Nat., vol. xxviii, pp. 881–884. Also an important "Note on Mr. Kummel's review," concerning the gradient of the valleys. Jour. Geol., vol. iii, pp. 497–498, 1895.

4. "The Yumuri Valley of Cuba—a rock basin." Geol. Mag. Lond., IV, vol. i, pp. 499–502, 1894.

5. "Preliminary Notes on the late Connection and Separation of the Pacific Ocean and Gulf of Mexico," Ib., vol. ii, pp. 306–308, 1895.

6. "Geographical Evolution of Cuba," Bull. Geol. Soc. Am., vol. vii, pp. 67–94, 1896 (with more details of the submarine valleys and their geological relationship, terraces, etc.).

7. "On the Continental Elevation of the Glacial Period," Geol. Mag. Lond., IV, vol. v, pp. 32–38, 1898 ; Abstract B. A. Rept. for 1897, pp. 651–652. (This contains a notice of the recurrence of the submarine valleys, on both sides of the North Atlantic and in the Arctic Sea. It was preliminary to No. 23.)

8. "Geological Canals between the Atlantic and Pacific Oceans." Abstract preliminary to No. 9. Proc. Am. As. Ad. Sc., vol. xliv, pp. 139–140. 1896.

9. "Great Changes of Level in Mexico and the Interoceanic Connections," Bull. Geol. Soc. Am., vol. ix, pp. 13–34, 1898. (Here is shown changes of level complementary to those indicated in the submarine valleys.)

10. "Late Formations and Great Changes of Level in Jamaica." Trans. Can. Inst. Toronto, vol. v, pp. 324–357, 1898. (With further details of the relationship of the submarine valleys to the land features, of the characteristics of the submarine platforms, of land connections, etc.) Abstract in this Journal, IV, vol. vi, pp. 270–272, 1898.

11. "Resemblances between the Declivities of High Plateaus and those of Submarine Antillean Valleys." Trans. Can. Inst. Ib., pp. 359–368. Abstract this Journal, IV, vol. vi, pp. 272–273, 1898. (Showing the gradients of both kinds of valleys by steps, an important supplement to the Antillean paper, No. 3.)

12. "The West Indian Bridge between North and South America," Pop. Sc. Monthly, vol. liii, pp. 10–30, 1898.

13. "Geological Waterways across Central America," Ib., pp. 577–593.

14. "Prof. Hull's 'Submerged Platform of Western Europe.'" Geol. Mag., Lond., IV, vol. vi, pp. 16–18, 1899.

15. "Mr. Huddleston's 'On the Eastern Margin of the North Atlantic Basin.'" Ib., pp, 559–566. (A reply to his criticism of Prof. Hull's work.)

16. "The Windward Islands of the West Indies." Trans. Can. Inst., vol. vii, pp. 351–370, 1901.

17–22. "On the Geological and Physical Development of :— Antigua ; Guadeloup, Anguilla, St. Martin, etc. ; St. Christopher Chain and Saba Banks ; Dominica; with notes on southern

islands, Barbadoes and Trinidad." Six papers in Quar. Jour. Geol. Soc., Lond., vol. lvii (1901), pp. 490–544 and vol. lviii, pp. 341–365. (The local development of the insular shelves, the submarine channels and valleys, and their associated geological and physiographic relationships are considered, while in No. 16 they are further correlated.)

23. "The Submarine Valleys Off the American Coast and in High Latitudes," Bull. Geol. Soc. Am., vol. xiv, pp. 207–226, 1903. (This is an amplification of No. 7 and a delayed continuation of the paper on the Antillean Continent, No. 3.)

24. "The Submarine Great Canyon of the Hudson River," this Journal, IV, vol. xix, pp. 1–15, 1905. (The most perfectly explored of all the American canyons.)

25. "On the Physiographic Improbability of Land at the North Pole," as in this Journal preceding this list. (An application of the study of Submarine valleys to exploration of the unknown Arctic region.)

26. "Prof. Hull's 'Sub-oceanic Terraces and River-Valleys off the Coast of Europe.'" A Review. Am. Geologist, vol. xxxv, 13 pages (in press), 1905.

27. "Dr. Nansen's 'Bathymetrical Features of the North Polar Sea, with a Discussion of the Continental Shelves and the Previous Oscillations of the Shore-Line." A Review. Am. Geologist, vol. xxxv, 15 pages (in press), 1905. In this Dr. Nansen discusses American valleys.

The study of the submarine valleys is in its infancy, and while the work in the above papers somewhat overlaps and embraces many features, these have been considered incidental to working out the submarine channel, valleys, etc., dissecting the submarine border of the continent. These valleys are regarded of atmospheric origin from the facts brought out, therefore they become evidence of great changes of level of land and sea. Some of the consequences of such changes are considered. But only a commencement of the great problem has been inaugurated.

While references have been made to the work of others in the writer's papers, the addition of the following contributions will make a nearly complete list, so far as America is concerned. As to Europe, the references in the papers of Prof. Edward Hull and Dr. Fridtjof Nansen are equally comprehensive.

Prof. J. D. Dana: "The Hudson River Channel;" in all editions of The Manual of Geology (1863–1895).

"Long Island Sound in the Quaternary Era, with observations on the Submarine Hudson River;" this Journal (3), vol. xl, pp. 425–437, 1890. (In all cases the submarine channels are regarded as submerged valleys.)

Prof. A. Lindenkohl: "Geology of the Sea Bottom in the approaches to New York Bay," this Journal (3), vol. xxix, pp. 475–480, 1885.

"Notes on the Submarine Channel of the Hudson River, and other evidences of Postglacial Subsidence of the Middle Atlantic Coast Region. This Journal (3), vol. xli, pp. 489–499, 1891 (in which the channel was differentiated, with the recognition of the continuing canyon to a depth of about 3000 feet).

Prof. George Davidson: "Submarine Valleys of the Pacific Coast of the U. S." Bull. Cal. Acad. Sc., vol. ii, pp. 265–268, 1887. (Calling attention to the valleys and describing three of them, without discussion of origin.) Others are described in his Pilot of the Pacific Coast, 1889, pp. 35–36, 51–52. (He refers to having later designated them "submerged.")

"The Submerged Valleys off California (U. S.), and of Lower California (Mexico). Proc. Cal. Acad. Sc. (3), vol. i, pp. 73–103, 1897. (Here the Continental Shelf is considered, 31 submerged valleys are described dissecting it, and the features of the adjacent land are given. Several are traced to 2000 feet, one to 3600, and one to 5000 feet below the surface of the sea.)

Dr. Warren Upham: "Quaternary Changes of Level;" Geol. Mag. Lond. (3), vol. vii, pp. 492–497, 1890.

"The Fjords and Lake Basins of North America considered as evidence of Preglacial elevation, and depression during the Glacial Period." Bull. Geol. Soc. Am., vol. i, pp. 563–567, 1890. (He also treats of some foreign examples.)

"Submarine Valleys on Continental Slopes;" Abstract, Proc. Am. As. Ad. Sc., vol. xli, pp. 171–173, 1892.

"Fjords and Submerged Valleys of Europe;" Am. Geol., vol. xxii, pp. 101–108, 1898.

Prof. Joseph Le Conte: In Tertiary and Post Tertiary Changes of Atlantic and Pacific Coast," etc. Bull. Geol. Soc. Am., vol. ii, pp. 323–330, 1890. (Discusses the submerged valleys as such, with their beheading by orogenic movements.)

In "Earth-Crust Movements and their Causes;" Bull. Geol. Soc. Am., vol. viii, pp. 113–126, 1897. (He discusses the oscillations which favored the excavation of land valleys, and subsequently submerged them.)

Prof. A. C. Lawson: In "The Geology of Carmelo Bay;" Bull. Univ. Cal. (Geol. Dept.), vol. i, pp. 57–59, 1893, also page 155 (in which he briefly discusses the submarine valleys, believing them to be structural).

Prof. Harold W. Fairbanks: "Oscillations of the Coast of California during the Pliocene and Pleistocene." Am. Geol., vol. xx, pp. 213–245, 1897. (Discusses the submarine valleys, pp. 228–245, with the conclusion that they are submerged land valleys formed in the early Pleistocene days.)

Mr. W. S. Tangier Smith: "The Submarine Valleys off the California Coast," Science, vol. xv, pp. 670–672, 1902. (He suggests that some of the submarine valleys were made or opened by subterranean streams.)

Prof. N. S. Shaler: "Evidences as to the Changes of Sea Level." Bull. Geol. Soc. Am., vol. vi, pp. 141–166, 1895. (Discusses drowned harbors, that of St. Lawrence, etc., subterranean channels of Florida, etc.)

Art. XXXVI.—*On an Interesting Variety of Fetid Calcite and the Cause of its Odor;* by B. J. Harrington.

About fifty years ago, when Sir W. E. Logan was studying the geology of the Grenville region in Canada, he came upon an interesting variety of calcite in the township of Chatham (lot 10, range xi) which emitted "when rubbed an overpowering odor like that of sulphuretted hydrogen."* In the "Geology of Canada," published in 1863, Dr. T. Sterry Hunt again called attention to what is evidently the same material, as follows: "We may here notice a peculiar variety of fetid carbonate of lime, which forms a large bed in the Laurentian series, in Grenville. It is a very coarse-grained, cleavable, milk-white and apparently pure calcite, which when struck or very lightly scratched, evolves a most powerful and unpleasant odor, recalling somewhat that of phosphuretted hydrogen. It dissolves without residue in dilute acids, and the carbonic acid gas evolved does not affect solutions of lead or silver salts, so that it is difficult to say to what the peculiar smell of this singular rock can be due. It is entirely distinct from the bituminous odor, which is evolved by percussion from a great many of the limestones of the Palæozoic series, or from that produced by striking some siliceous rocks."

Specimens of this interesting calcite have long been in possession of the writer, and it was felt that it should be possible to arrive at some definite conclusion with regard to the cause of the fetid smell. Thin sections were in the first instance studied and showed under the microscope the presence of great numbers of very minute cavities, evidently containing a liquid, as moving bubbles due to the contraction of the liquid could occasionally be seen. These cavities suggested the presence of hydrogen sulphide in a liquid condition or possibly in solution in water. If the gas were present in either condition, it was obvious that it would be liberated either by solution of the calcite in an acid or by pulverizing the mineral; further, that the finer the degree of pulverization the more hydrogen sulphide would escape. This was fully confirmed by experiments made both by the writer and by Mr. Lloyd Lodge, demonstrator in the chemical department. It has been found, moreover, that Hunt's observation with regard to the action of the escaping gas upon solutions of lead or silver salts is erroneous, for in both cases black precipitates are obtained, while in the case of cadmium salts the characteristic yellow precipitate is produced. The inference would appear to be

*Geological Survey of Canada, Report of Progress, 1853–54–55–56, p. 23.

that Hunt worked with the finely pulverized mineral, from which most of the hydrogen sulphide had been liberated, or that the gases were not passed into the solutions of the salts in question for a sufficient length of time.

A specimen of the calcite was found to have a specific gravity of 2·713 and gave on analysis the following percentage composition:

Lime	55·330
Magnesia	0·540
Ferric oxide	tr
Carbon dioxide	43·925
Sulphur as H_2S	0·016
Phosphoric anhydride	tr
Insoluble matter	0·026
	99·837

The sulphur was determined by dissolving the mineral in dilute hydrochloric acid, passing the evolved gases into an alkaline solution of cadmium chloride and weighing the precipitate of cadmium sulphide. In the estimation of the phosphoric anhydride the mineral was dissolved in nitro-hydrochloric acid, so that if any phosphorus were present as phosphide its oxidation to orthophosphate might be ensured. As the quantity of insoluble matter was insignificant, the determination was made upon about thirty grams of mineral—hydrochloric acid being the solvent. The filtrate from the insoluble matter was tested for sulphates, but gave no precipitate with barium chloride. In the analysis of another specimen of the calcite Mr. Lodge obtained results very similar to the above, but found a slightly higher percentage of hydrogen sulphide (0·021).

The following figures illustrate the different results obtained in determinations of the hydrogen sulphide according to the coarseness or fineness of the calcite:

	Lumps.	Powder of medium fineness.	Very fine powder.
H_2S from 29·45 grams of mineral	0·00471	0·00176	0·00035
Percentage of H_2S	0·01600	0·00560	0·00120

The figures show that the fine powder contained less than $\frac{1}{13}$th of the amount present in the unpulverized material, and had the grinding been further prolonged there would no doubt have been a still greater difference.

On grinding a few fragments of the calcite under water in a porcelain mortar and filtering, the water contains sufficient hydrogen sulphide in solution to give the appropriate color

reactions with salts of silver, lead, cadmium, etc. If, again, the calcite be gently heated in a test-tube, hydrogen sulphide is liberated, and on heating somewhat more strongly the mineral generally decrepitates and gives off more hydrogen sulphide. On heating to 160° C. it shows a strong, deep yellow phosphorescence which persists for several minutes after removal from the source of heat.

From what has been stated it is evident that the hydrogen sulphide is the cause of the odor evolved when the calcite is scratched or rubbed, and although the quantity seems small when stated as percentage by weight it amounts to about 500 cubic inches of the gas per cubic foot of the mineral. Per cubic yard this would be about 13,500 cubic inches (a barrel and a half) of the gas, and the total quantity bottled up in the limestone of the region must be exceedingly large. It may exist in the calcite in a liquid condition, as in the case of the liquid carbon dioxide so frequently present in quartz, or in conjunction with water, or even with carbon dioxide. Mr. Douglas McIntosh, M.Sc., lecturer in chemistry, has kindly made some experiments for me which are interesting in this connection. He found that if solid carbon dioxide be dropped into liquid hydrogen sulphide and the tube sealed, as the temperature rises to that of the room the carbon dioxide dissolves and a homogeneous liquid is obtained, giving no evidence so far as appearance is concerned of the presence of two distinct compounds.

A small quantity of distilled water, again, was put into a tube and frozen, an equal volume of liquid hydrogen sulphide added and the tube sealed. When the ice melted, the two liquids could be seen to be separated by a distinct film—possibly of sulphur—which prevented their intermixing. In most cases when the tubes were heated they burst before the temperature reached 100° C. The same was also true if the tubes were inverted in position, that is with the water above the hydrogen sulphide; after standing for a short time the film gave way and the tube burst, possibly because of some sudden reaction between the two liquids. In one case, however, a tube which showed the distinct film separating the two liquids was forgotten and allowed to stand for some weeks. The film had then disappeared and, so far as one could tell by the eye, the two liquids had completely intermixed. On cooling the tube until the water crystallized out and then allowing it to gradually attain the temperature of the room, no separation of the two liquids took place. This would indicate that under the conditions of pressure in the tube, mutual solution of the water and hydrogen sulphide had taken place, and similar conditions may exist in the case of the fluid-cavities of the calcite.

Sir William Logan, judging from his description, regarded the fetid calcite as a local modification of one of the great bands of limestone belonging to the Grenville series. This modification might have been due to some form of solfataric action going on at the time of crystallization and introducing hydrogen sulphide, one of the usual accompaniments of such action. The crystals of pale green tourmaline (a boron mineral) which occasionally occur in the calcite might also point to solfataric action, though no such assumption is necessary to account for its presence. The hydrogen sulphide, again, might be taken as an indication of the existence of organic matter in the old sediments of the Laurentian series; for, as is well known, organic matter in presence of water reduces alkaline and earthy sulphates to sulphides, which reacting with water and carbon dioxide produce hydrogen sulphide. On the other hand, however, the hydroden sulphide might have been produced from sulphides formed in the earth's crust quite independently of any organic agencies.

Associated with the fetid calcite there is also a white, translucent to subtranslucent quartz, which, on striking with a hammer or scratching with a knife, likewise evolves hydrogen sulphide. When fragments of the quartz are heated in a test-tube, considerable quantities of the gas are given off and readily darken lead acetate paper. No attempt has been made to estimate the proportion of the hydrogen sulphide in this case, nor does there seem to be any simple way of accomplishing this. In lump form the mineral would dissolve too slowly in hydrofluoric acid, while if powdered most of the hydrogen sulphide would escape. On heating the fragments, too, only a portion of the gas can be liberated and that in part at least is liable to undergo dissociation at the temperature of the experiment. The fluid-cavities in the quartz are, however, larger than in the calcite and more readily admit of study. Most of them afford no visible evidence of the presence of more than one liquid, and the moving bubble which they contain does not disappear on heating to 150° C—the highest temperature tried. In a few cases the bubbles disappeared at from 32°–35° C., indicating, no doubt, that the cavity contained liquid carbon dioxide whose critical temperature is 32° C. In one case the critical point was 40° C, and in several others from 60°–65°, indicating, possibly, mixtures of carbon dioxide and hydrogen sulphide, the critical point of the latter being about 100° C. In cases where the bubbles did not disappear water is evidently present, accompanied no doubt by hydrogen sulphide and possibly by carbon dioxide as well. Some of the cavities, again, appear to contain two separate liquids with a bubble in one of them.

McGill University, Montreal.

ART. XXXVII.—*Alternations of Large and Small Coronas observed in Case of Identical Condensations produced in Dust-free Air saturated with Moisture;** by C. BARUS.

1. *Apparatus.*—By dust-free air, I mean air which has been passed through a packed cotter filter. My filters are 16 inches long, conical, tapering from about 2 inches in diameter at the large end to about one-half inch at the other. They contain absorbent cotton rammed in from both ends and kept in place by wire. When filtered air is required, the stop-cock is only just opened so that influx of dust-free air may be extremely slow. This insures proper filtration and does not interfere with the saturation of the air in the fog-chamber. In this paper condensation was produced in a long glass cylinder, 16 inches from end to end and 5½ inches in diameter, placed horizontally and normal to the line of sight. It contained a rectangular framework of copper wire covered with wet cotton cloth, except on the two opposed broadsides through which the coronas were observed. The distance between the bottom (water) and the roof of the rectangular framework was about 9 centims. The provisions for keeping the air saturated are thus ample.

The vacuum chamber was a large boiler of galvanized iron, having a capacity V, of over $100{,}000^{\text{cub cm}}$, while the capacity v, of the condensation chamber is about $6{,}700^{\text{cub cm}}$, so that the volume ratio, v/V, is but ·063. The two chambers are connected by about a foot of rubber tubing over one inch in bore, usually containing a one inch plug gas cock. An instantaneous clapper valve of the same dimensions and opened with a hammer was often used for comparison. Later the glass fog-chamber was advantageously replaced by one of waxed wood (cf. this Journal, xlix, p. 175, 1905), with the opposed sides, through which the coronas were observed, made of plate glass. The internal dimensions in this case were $55\times10\times20^{\text{cub cm}}$, and the volume ratio, v/V, in connection with the vacuum chamber about ·13.

2. *Manipulation.*—The experiments were conducted as follows: Having selected a suitable pressure difference above that at which condensation in dust-free air just begins (usually termed the *fog-limit* in the present paper), the dust-free moist air in the closed condensation chamber at atmospheric pressure is suddenly exhausted and the corona measured. After all fog has subsided the exhaustion cock is closed and the filtered air very slowly admitted. The operations are then repeated allowing time (about 2–3 min.) for saturation. Under all circumstances the treatment for large and small coronas was identical.

In the given apparatus, condensation in dust-free moist air began at the pressure difference, $\delta p = 22{\cdot}5$ for an atmosphere

* Read to the Am. Physical Soc., Feb. 25, 1905.

of 76^{cm} corresponding to the volume expansion of about 1·43. The pressure difference usually applied in the experiments was $\delta p = 31{\cdot}2$, and the volume expansion 1·72.

3. *Alternation of large and small coronas* (*periodicity*). *Data.*—The small coronas are usually sharp; but the large coronas appear blurred and filmy, accompanied with much rain. Remembering that all operations are conducted in a way strictly the same, the annexed figures 1 to 4 shows the coronas seen in the successive exhaustions. The angular diameter or aperture is $\sin \phi/2 = s/60$, or nearly $\phi = s/30$. The eye at the goniometer was about 40^{cm} from the axis of the condensation chamber (placed as close as possible to insure clearer vision) and the source of light 250^{cm} beyond it. Observations were made along the axis of the cylinder, placed horizontally.

In the case of 2 min. periods between the exhaustions (fig. 1) the periodicity is maintained without exception. For brevity let the smaller coronas be called inferior, the larger coronas superior. Frequently a very small inferior corona l evokes a relatively large superior corona h, or larger inferior coronas are followed by smaller superior coronas; but this is not always the case. As a more general rule, if the aperture is intermediate between the inferior and superior coronas, the succeeding corona is of the same size and oscillation terminates. Similar remarks may be made relative to the diagram, fig. 2, for 3^{m} periods between the exhaustions, or for fig. 4, for the case of dust-free air energized by weak radium (10,000 ×) in sealed glass tube.

4. *Remarks on the results.*—It will conduce to clearness to take the increase of apertures, s, with the increase of pressure difference, δp, first in order. If the exhaustion is insufficient, the groups of smaller nuclei will escape precipitation and the coronas be relatively small. After all nuclei, large and small, are caught, higher sudden exhaustion can no longer increase the apertures. More water is instantaneously precipitated per cubic centimeter. Nevertheless this counter-effect, if it is such, will also vanish with increasing pressure differences, because of the accentuated rapidity of thermal radiation. The adiabatic method ceases to be effective. Finally the necessity of producing sudden cooling simultaneously with extreme dilatation is a complication; for in view of the relative slowness of diffusion, it will eventually be impossible to keep the instantaneously dilated water vapor saturated, without arresting the growth of the fog particles. Above $\delta p = 40^{cm}$ the effect of sudden exhaustion may be conceived to actually dry the air, seeing that the density of vapor is instantly reduced more than one half, and hence even slight differences of supersaturation at the outset may show themselves effectively at these high exhaustions. Experimentally (figs. 6 and 7), these surmises are not fully

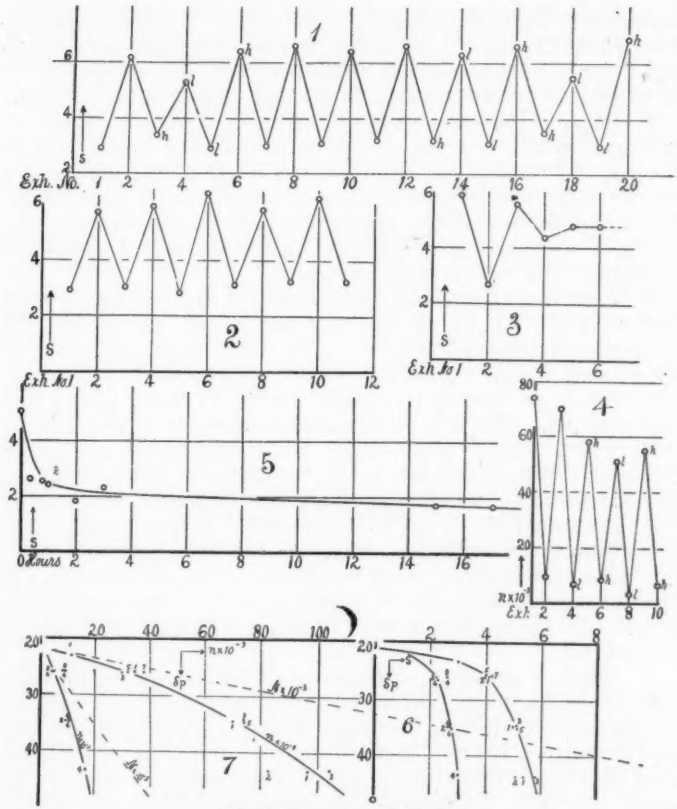
borne out: while the s-curves usually tend to reach an asymptote or a maximum, the N-curves (number of nuclei per cm^3 computed for normal pressure and temperature) do not usually do so, at least so far as observed in the case of non-energized air.

5. *Blurred coronas.*—The occurrence of an abundance of rain with all the coronas, as well as the blurred appearance of the coronas themselves, shows that gradation of particles is a characteristic feature with all these condensations. The following results for periodicity apparently indicate the presence of a group of markedly large particles in the amount of about 1/8 or more of the total number of nuclei.

6. *Time loss of nuclei.*—In the lapse of time exceeding even half an hour (cf. fig. 5) the aperture of all coronas usually diminishes in marked degree. Above the fog-limit, however, the coronas do not vanish as the result of repeated exhaustion; i. e., the air can not be freed from nuclei by being stored in a closed vessel. What is particularly remarkable is the rapidity with which nuclei precipitated by condensation are again replaced. Whether these come through the filter in quasi-gaseous form, or whether they are spontaneously produced in the imprisoned air is yet to be decided. In every case something has to be explained away. If the nuclei came through the filter, for instance, they would not come periodically. If inferior coronas were due to undersaturation, superior coronas should be obtained in the lapse of time; the reverse of which is observed.

7. *Effect of pressure difference.*—With increasing pressure differences, δp, the superior and the inferior apertures each lie on distinct curves, as in figures 6 and 7, both of which rise rapidly at first, are then rapidly retarded and tend to reach distinct maxima. The limiting ratio of apertures is liable to be nearly one-half. If, however, the pressure difference is carried far enough, both s-curves sometimes change character by decreasing and increasing respectively, eventually to reach a common value. If then pressure difference is in turn reduced from these final values, the oscillation of s is usually absent and a mean nucleation appears at all subsequent (decreasing) pressure differences.

8. *Continued.*—The increase of nucleation, n, or N, with the pressure difference, δp, is often difficult to interpret, since the inferior and superior values are so much more widely and irregularly distributed. The n-curves usually show two limiting rates of increase of n with δp, respectively very large and very small. This is particularly well brought out in the data of figure 7 where both loci are nearly straight even above $\delta p = 40^{cm}$. Inferior coronas are sometimes absent and those observed present an accentuated case of superior corona; and vice versa.



LEGENDS FOR FIGURES.

CURVE 1.—Periodicity of dust-free air, showing the angular apertures of coronas (ordinates s) in successive identical exhaustions (numbered by abscissas), made at two-minute intervals apart. Note that high (h) inferior coronas are usually followed by low (l) superior coronas and vice versa; while high superior coronas are followed by high inferior coronas. $\delta p = 31 \cdot 2^{cm}$.

CURVE 2.—The same for three-minute periods between the exhaustions.

CURVE 3.—The same for five-minute periods. Periodicity gradually vanishes.

CURVE 4.—Periodicity of dust-free air energized by radium (10,000 ×) in glass, within the fog chamber. The successive exhaustions gradually reduce the nucleation. Sequences of h and l are apparent. The ordinates are number of nuclei per cm^3. $\delta p = 25^{cm}$.

CURVE 5.—Dust-free air not energized, showing the reduction of nucleation (decreasing apertures, s) in the lapse of time.

CURVE 6.—Periodicity of apertures (s) at different pressure differences δp. The number of the exhaustions is attached to the observation. The loci of inferior and superior coronas are well marked.

CURVE 7.—The same computed for number of nuclei (N) in one cub. cm. of air at normal pressure.

9. *Fog-limits.*—An interesting feature of these results are the fog-limits or pressure differences at which condensation in dust-free air just commences. In spite of the different sizes of apparatus and valves used, the fog-limits are about the same, viz.:

$\delta p = 22$–23	Apparatus, wood,	$v/V = \cdot 13$	Valve, plug.
21·5–	" glass,	$v/V = \cdot 06$	" clapper.
22–23	" "		" plug.
21–23	" "		" clapper.
22–23	" "		" plug.

These results are surprising, inasmuch as the effect of the volume ratio of fog and vacuum chambers and the valve effect would naturally be looked to as productive of larger differences. With other apparatus (this Journal, vol. xix, p. 175) the data were

$\delta p = 22$	Apparatus, wood,	$v/V = \cdot 7$	Valve, plug.
20	" "	$\cdot 7$	" clapper.

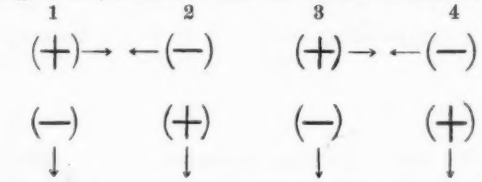
Thus the supreme importance of mere rate of exhaustion may well be called in question until more definite results appear; for with so large a difference of volume ratio v/V, of valve obstruction, etc., the essential features should appear more clearly. One may note that if colloidal molecules (extremely fine nuclei) pass through the filter, these would capture most of the moisture on condensation. It is possible therefore that if the filter is dispensed with and a closed vessel used, larger coronas will appear at smaller pressure differences for this reason.

10. *Alternations of large and small coronas.*—Effectively, the case of oscillation is one in which the large sparsely distributed fog particles emit more nuclei and the very abundant small fog particles fewer nuclei; i. e., the phenomena may be looked upon as though the nuclei were generated during the growth of the fog particles. This plausible explanation, however, is not easily maintained; for the emission would have to be as the growth of surface, in other words as the volume, and the number of particles varies inversely as their volume. A counter supposition may be hazarded to the effect that the fog particles of large coronas absorb more nuclei because of their abundance than the fog particles of small coronas. But the period of suspension of particles is too short to be of moment.

If negative ions are more active as condensation nuclei than positive ions, the results observed may be tentatively grouped in according with the following scheme (see diagram, p. 354).

Let the ions be originally neutral as a whole, and suppose, as in case 1, that the negative ions are first precipitated. In the interval between this and the next exhaustion fresh ions are generated or taken in through the filter, as shown in case 2. If these negative ions partially neutralize the positive ions left over in case 1, the second precipitation takes place on the

positive ions. Thereafter, case 3, the first is repeated, etc. But if the coronas are taken as a measure of the number of particles, the number of effective nuclei must be about eight times larger in the first case than in the second, whereas the



ions should be present in equal numbers. Hence there is serious objection to this hypothesis at the outset, quite apart from the numbers obtained, which are enormously too large.

11. *Undersaturation.*—Some mechanism of this kind is nevertheless probable, and it will work equally well if the undersaturation produced by the precipitation of fog particles is not rapidly made up by diffusion and convection. Of all hypotheses that of undersaturation has the broadest bearing and accounts qualitatively for most of the phenomena, as will presently be pointed out in detail. True, the large coronas must be supposed to carry down more moisture than the small coronas, but the difference need not be great. The hypothesis encounters a serious obstacle inasmuch as the coronas obtained from saturated air which has been imprisoned for long intervals of time (§ 8), are usually an extremely small type of inferior corona, whereas they should be large superior coronas. Long intervals of waiting between exhaustions brings out not a superior corona but at best one of intermediate size. Another precarious feature is suggested by computating the rate at which saturation should be established in the most unfavorable case of the middle air layer, between the wet top and bottom of the fog chamber, for diffusion alone.

In fact if diffusion takes place from the wet top and bottom of the rectangular trough of height a, into a partially saturated atmosphere of initial vapor pressure p_0, then at any time t, at the middle plate $x = a/2$

$$p = 1 + \frac{4(p_0 - 1)}{\pi}\left(\sin\frac{\pi}{2}\epsilon^{-(\pi/a)^2kt} + \frac{1}{3}\sin\frac{3\pi}{2}\epsilon^{-(3\pi/a)^2kt} + \text{etc.}\right)$$

where $dp/dt = k\ (d^2p/dx^2)$. Hence if $a = 11^{cm}$ as in the largest trough (wood), and if $k = \cdot 23$, the following values obtain.

$t =$ 30	$p_0 = 0$, $p =$ ·28	$p_0 = 1/3$, $p =$ ·52	$p_0 = 2/3$, $p =$ ·76
60	·59	·72	·86
120	·87	·91	·96
180	·96	·97	·99

In the above tables a was usually less than 10^{cm} (glass fog chamber), making the condition correspondingly favorable.

Hence by diffusion alone there should be saturation after two to three minutes even at the most distant (middle, $x = a/2$) plane, to within a few per cent; for the central layer is probably always more than half saturated at the outset. In addition to diffusion, however, there is marked convection due to the lightness of water vapor. At the same time there is no evidence that the more numerous but small drops of the superior coronas carry down a sufficient excess of water; nor are the coronas, though blurred otherwise distorted, as they would be for a definite diffusion gradient.

12. *Continued.*—Assuming however that undersaturation does occur and is oscillatory as the result of successive larger and smaller precipitations, the cases may be interpreted in succession as follows;

a. The superior coronas carry down more moisture and should apparently be followed by even larger coronas; and vice versa: but after the fog particles producing the superior coronas are precipitated, the supersaturation possible for the given pressure difference applied no longer catches the small nuclei. Hence the inferior coronas appears in succession. Hence also, apart from what may be time errors in opening the stopcock, very large pressure differences tend to wipe out the oscillation as all the nuclei are captured.

b. The ratio of 1:2 for coronal apertures and of 1:8 for the numbers of fog particles seems out of keeping with the slight differences of supersaturation instanced in 13; but this is again a question of catching the smaller nuclei as a group.

c. The phenomenon is much too definite an oscillation of aperture between s and $2s$ (nearly) to be referable to an irregular cause like deficient supersaturation; but the two types of nuclei admit of a wide range of saturation, as long as there is a correspondingly wide difference in the sizes of nuclei.

d. A series of minor observations are favorable to the hypothesis of residual undersaturation; as for instance, the eventual coalescence of the aperture curves of the superior and the inferior coronas; the dew effect; the fog effect and shaking; the fact that very small inferior coronas are followed (caet. par.) by large superior coronas while the latter are followed by large inferior coronas, etc.

e. Finally, while superior coronas are followed by inferior coronas and vice versa, mean coronas follow each other.*

13. The values of the nucleation (number of nuclei per cub. cm.) of the inferior and the superior coronas naturally

* I have since proved that periodicity is due to the formation of water nuclei by evaporation. On these the inferior coronas condense. Points *a* to *e* then follow. The ions become solutes.

present a more striking contrast, since the third power of aperture is involved. Otherwise but few new results are to be inferred from them. If the long series of figure 1 be taken, which contains the data of twenty successive alternations, the average inferior nucleations are 11,800, and the average superior nucleations 94,000, supposing, of course, that the precipitated water is the same in both cases and that it is all condensed on the available nuclei. In other words, if the two cases are otherwise identical, the superior coronas correspond to a number of nuclei eight times greater (frequently larger than this in the other observations) than the inferior coronas. As this explanation is the more probable, it follows that the nuclei (as stated in § 10) cannot be regarded as positive and negative ions. They are rather the groups of large and small nuclei seen throughout the condensations in connection with the rain and the blurred coronas. Apart from this the numbers obtained throughout are quite out of keeping with any similarly observed ionization. If, however, free electrons appear only at the destruction or at the origin of nuclei, the association of few ions with many nuclei at any time subsequent to their origin, is well accounted for, as already suggested in the earlier paper. It is only while the nuclei are being produced that the ionization and the nucleation must be of the same order; for the latter persists while the former vanishes at once. Finally the following results are implied at least for the physical structure of air saturated with water vapor:

Air (dust-free) is inseparably intermixed with large and small nuclei, whose number (to be reckoned in millions per cubic centim.) rapidly increases as the order of molecular size is approached. There seems to be no objection to looking upon these nuclei as a kind of colloidal (air) molecule, particularly as such molecules are frequently producible by the means (Bredig) which produce nuclei. If a large number of free atoms is suddenly introduced into any region (and this is probably what the radiation of the above kind virtually does), the result is not merely a production of typical molecules but of a large concomitant of graded nuclei.

Practically any given nuclear status of air is a counterpart of the intensity of the ionization of the medium in which the nucleation originated, to the effect that the superior limit of size of the nuclei and their number increase with the ionization. But there is no case of ionization free from nucleation, be the exciting cause a mere radiation as above, or ignition, combustion (including the low temperature cases like phosphorus), or high potential discharge, or violent comminution as in the case of water nuclei,—the two manifestations being often distinguishable by enormously different rates of decay.

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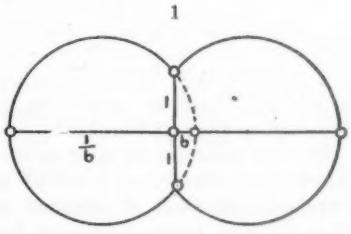
ART. XXXVIII.—*New Circular Projection of the Whole Earth's Surface;* by ALPHONS J. VAN DER GRINTEN, Chicago.

THE representation of the surface of a sphere upon a plane is a problem which has occupied the attention of cartographers for centuries. The problem has been solved in many ways, but always at some sacrifice of form or relation of parts, depending upon the requirements of conformity or equivalence.

Conformal projections necessarily exaggerate the areas toward the margin (Eisenlohr, August, et al.), while the equivalent ones (Werner, Mollweide, Sanson) reduce the angles formed by the intersection of parallels and meridians considerably. Each of these devices introduces such errors of representation that a comparison of areas and places in the different parts of the globe becomes rather difficult. A third principle, introduced in an attempt to distribute these errors over the map, also fails to obtain the most favorable result, an increase of distortion in tropical latitudes hardly being offset by an increase in accuracy in the less important polar regions.

These conditions, therefore, make desirable a new method of projection, by which all the deformations shall increase regularly from a zero value at the equator to the least possible maxima at the poles. The network may be formed exclusively by straight lines and circular arcs, as the polar flattening can be neglected as unimportant in a map of so small a scale as is required to represent the whole earth's surface.

The device of using circular arcs for parallels and meridians results in the production of an apple-shaped marginal meridian, having the central meridian and the equator as straight lines. If b represents the ratio of the lengths of these main lines of the projection, a mathematical investigation shows that the most favorable expression of the total deformation, dependent upon the elements h, k and Θ, as will be shown later, is obtained when the two circles, the marginal meridians of the two hemispheres, cover each other, so fusing into one true circle: $b = 1$. The mathematical deduction as given here, for this case, is based upon Tissot's theories of deformation, as given in his famous "Mémoire sur la représentation des surfaces et les projections des cartes géographiques"



(1881), augmented by E. Hammer in "Die Netzentwürfe geogr. Karten, von A. Tissot, 1887."

J. H. Lambert (1772) was the first to recognize the circular form as the most natural one for the representation of the whole globular surface, but failed to notice the fact that his conformal projection would admit of a simple geometrical construction. Even the most modern treatises on projections reprint his table containing the numerical values of the distances d and s of the parallels and their centers from the equator. Recently Zöppritz, Reclus and others have urgently recommended the circular form of representation, not only for the whole earth, but for parts of it as of the continents. Although Lambert's projection must be considered as a theoretical "Unicum" its insufficiency for practical purposes becomes evident, in the stereographic arrangement of the meridians, and the subsequent primary subdivision $\left(c = \tan\frac{\phi}{2}\right)$ of the central meridian, reducing too much the central parts of the map as compared with those near the margin.

In order to remedy this defect, I am proposing a projection in which the meridians intersect the equator at equal distances, and then the distances and curvatures of the parallels are altered in such a way that no alteration whatever occurs along the equator. Then we readily obtain our distance d, by substituting $c = \frac{\phi}{90}$ for $c = \tan\frac{\phi}{2}$ in Lambert's formula

$$d = \frac{\sqrt{1+\tan\frac{\phi}{2}} - \sqrt{1-\tan\frac{\phi}{2}}}{\sqrt{1+\tan\frac{\phi}{2}} + \sqrt{1-\tan\frac{\phi}{2}}} \text{ thus:}$$

$$d = \frac{\sqrt{1+c} - \sqrt{1-c}}{\sqrt{1+c} + \sqrt{1-c}} = \frac{1-\sqrt{1-c^2}}{c} = \frac{\sqrt{90+\phi} - \sqrt{90-\phi}}{\sqrt{90+\phi} + \sqrt{90-\phi}},$$

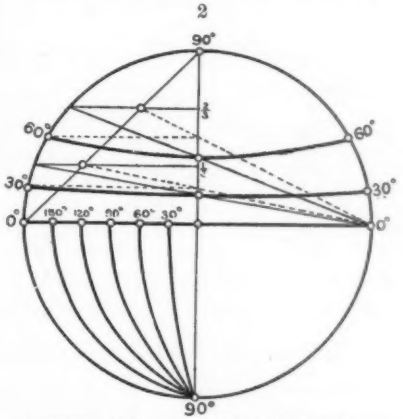
which can just as easily be constructed geometrically (see figure 2) as that of Lambert.

It now remains to determine the distance from the equator (y) of the intersecting point of any parallel and any marginal meridian, in such a manner that the distortion of angle ($\Theta = 90 - \eta$) formed by them be a minimum; inasmuch as the requirement of a minimum 2ω would necessitate a maximal Θ between the equator and the poles, as will be explained later in this paper.

y can be determined in different ways. If a rectangular network is proposed ($\Theta = 0$), we find $y = c = \frac{\phi}{90}$; if the paral-

lels are to run as straight lines parallel with the equator, we have $y = d$, in which case, although equivalence and conformity are preserved along the equator, Θ increases to 90° at the poles ($\eta = 0$); and finally if it is required that the deformation (κ) of any parallel at the marginal meridian shall be equal to its deformation at the central meridian, in which case all the parallels are practically intersected by the meridians at equal distances, we get

$$y = d\,\frac{3-d^2}{2}.$$



GEOMETRICAL CONSTRUCTION
Patented in U.S. Canada, Gr. Britain & France.

By the first arrangement (rectangular trajectories) the parallels at the margin would approach too near to the poles (h representing the deformation of meridional parts, ϕ the latitude, and λ the longitude):

$$h\,{}^{\phi=0}_{\lambda=180} = 2;\quad h\,{}^{\phi=90}_{\lambda=180} = h\,{}^{\phi=90}_{\lambda=0};$$

in the second case they would appear to be too far distant from the poles:

$$h\,{}^{\phi=90}_{\lambda=180} = \infty \,.\, h\,{}^{\phi=90}_{\lambda=0};$$

finally in the third case we are confronted with an unhappy congestion of the temperate zones:

$$h\,{}^{\phi=0}_{\lambda=180} = \tfrac{3}{2};\quad h\,{}^{\phi=90}_{\lambda=180} = \sqrt{3}\cdot h\,{}^{\phi=90}_{\lambda=0}.$$

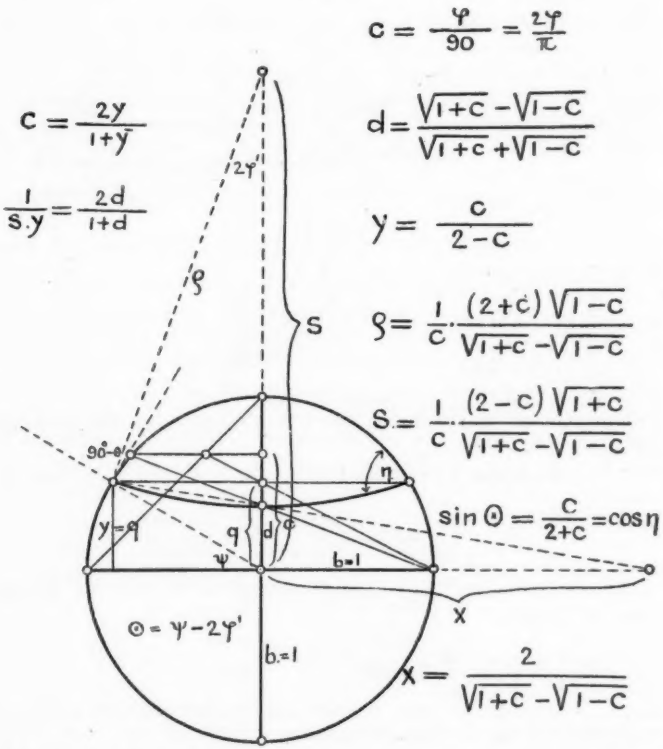
Therefore it seems desirable to find a middle ground by having all alterations continuously increased from zero at the equator to their least maxima at the poles:

$$h\,{}^{\phi=0}_{\lambda=180} = 1;\quad h\,{}^{\phi=90}_{\lambda=180} = \sqrt{2}\cdot h\,{}^{\phi=90}_{\lambda=0}.$$

This arrangement has the effect of making the continental regions fall within the zone of least "total error," though this

term must be used with reserve as no exact definition of it can be given; linear, angular, and areal values being of a heterogeneous character. Here it is the simplicity of the formula or construction which proves its superiority in the solution of an intricate problem.

3



The formula for our y can easily be developed by the following reasoning (fig. 3). The proportion

$$\frac{x}{x+\sqrt{1-y^2}} = \frac{d}{y} \text{ gives } y = d\,\frac{x^2+\sqrt{x^2(1-d^2)+d^2}}{x^2+d^2}.$$

Now in order to preserve conformity and equivalence along the equator (the meridians here being equidistant) we can substitute for x the arbitrary value $\frac{a}{d}$, which is to be so deter-

mined, that y comes nearest to $c = \frac{\phi}{90}$ for rectangular projection, making Θ, continuously increasing, a minimum. The above expression then is

$$y = d\,\frac{a^2 + d\sqrt{a^2(1-d^2)+d^4}}{a^2+d^4}\,;\ \text{and as}\ \sqrt{a^2(1-d^2)+d^4}$$

cannot exceed the unit ($d = 1$; $y = 1$), y will become a maximum, under the limitation $x^{\phi=0} = \infty$, and, therefore, Θ a minimum, just when $\sqrt{a^2(1-d^2)+d^4}$ is made a unit, giving $a = \sqrt{1+d^2}$, or $x = \frac{\sqrt{1+d^2}}{d}$, and finally $y = \frac{d}{1-d+d^2} = \frac{c}{2-c}$ and $\sin\theta = \sin(\psi - 2\phi') = \frac{d}{1+d+d^2} = \frac{c}{2+c}$. Any other value for a, less than $\sqrt{1+d^2}$, would produce a maximum of Θ between the equator and the poles. This maximum would reach its climax for $a = 1$, $x = \frac{1}{d}$ ($\Theta = 0$ at the equator and at the poles), the determination and location of which would require the solution of a very lengthy equation. The requirement of a minimal 2ω involves a much more intricate equation still for the determination and location of the maximal Θ that is formed between the equator and the poles.

The harmonic relation between y, c and the radius of the marginal meridian (= unity) is then defined by $c = \frac{2y}{1+y}$. Other harmonic relations occur at latitudes 72° and 54° as $y = \frac{2d}{1+d^2}$ and $y = \frac{2cd}{c+d}$ respectively.

I now offer the formulas of deformation in the most condensed form, which will furnish the necessary data for a table showing the most characteristic features of the circular projection in a numerical way; and which will enable the student of cartography to extend the table to apply to any interval of latitude whatsoever.

Deformation.

The deformation of an infinitely small part of the central meridian at a point $\left(\frac{\phi}{\lambda}\right)$ is expressed by the ratio $h_{\lambda=0} = \frac{\delta d}{r\delta\phi}$, r representing the radius of any globe. It being necessary to have $h_{\lambda=0} = k_{\lambda=0} = 1$ at the center of the map, we get

$$r = \frac{\delta d}{\delta \phi_0}, \; h_{\lambda=0} = \frac{\frac{\delta d}{\delta \phi}}{\frac{\delta d}{\delta \phi_0}}$$

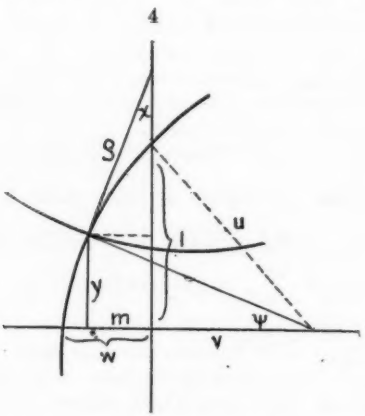
consequently (I) $h_{\lambda=0} = \frac{2}{c} \cdot \frac{\sqrt{1+c} - \sqrt{1-c}}{(1+c)\sqrt{1-c} + (1-c)\sqrt{1+c}}$.

The deformation of an infinitely small meridional part at the margin is defined by $h_{\lambda=180} = \frac{\delta \psi}{r \delta \phi}$. Now having $\sin \psi = y$, we finally get

$$(A) \; h_{\lambda=180} = \frac{y}{d} \cdot \frac{\sqrt{1-y^2}}{1-dy} \cdot h_{\lambda=0},$$

and in our case

$$(II) \; h_{\lambda=180} = \frac{4}{(2-c)[(1+c)\sqrt{1-c} + (1-c)\sqrt{1+c}]} = x.y.h_{\lambda=0}.$$



The deformation of a part of a parallel between two infinitely approximate meridians is explained by

$$k = \frac{\rho \delta x}{r \cos \phi \delta \phi} = \frac{\rho}{r \cos \phi} \cdot \frac{\delta(2\phi')}{\delta \phi},$$

from which is obtained the general formula

$$k = \frac{1}{r} \left(\frac{\delta u}{\delta \lambda} - \frac{\delta v}{\delta \lambda} \cos \psi \right) \cdot \frac{\frac{\delta w}{\delta \lambda}}{\cos \phi \cos \theta}$$

wherein u denotes the radius of any meridian, v the distance of its center from the central meridian and w the linear longitude. There we have $v = \frac{1-w^2}{2w}$; $u = \frac{1+w^2}{2w}$ and $\frac{\delta v}{\delta\lambda} = -\frac{1+w^2}{2w^2} \cdot \frac{\delta w}{\delta\lambda}$; $\frac{\delta u}{\delta\lambda} = -\frac{1-w^2}{2w^2} \cdot \frac{\delta w}{\delta\lambda}$ and substituting $k = \left(\frac{m}{w}\right) \frac{1}{\cos\phi}$, where $\left(\frac{m}{w}\right)$ becomes indefinite $= \frac{0}{0}$ at the central meridian, and find: $\left(\frac{m}{w}\right) = 1-d^2$; $k_{\lambda=0} = \frac{1-d^2}{\cos\phi}$ or finally,

$$\text{(III)}\quad k_{\lambda=0} = \frac{2}{c} \cdot \frac{(1+c)\sqrt{1-c} - (1-c)\sqrt{1+c}}{\sqrt{1+c} + \sqrt{1-c}} \sec\phi.$$

For the deformation k at the marginal meridian we get by the above general formula: $k_{\lambda=180} = \frac{\cos\psi}{\cos\phi\cos\theta}$, from which we derive: by (B) $\sin\theta = \frac{2d-y(1+d^2)}{1-d(2y-d)} = \frac{c-y}{1-cy}$ the general expression: (C) $k_{\lambda=180} = \frac{1-d(2y-d)}{(1-d^2)^2} \cdot k_{\lambda=0}$ and for our $y = \frac{c}{2-c}$:

$$\text{(IV)}\quad k_{\lambda=180} = \frac{(2+c)\sqrt{1-c}}{(2-c)\sqrt{1+c}} \sec\phi = \frac{\rho}{s} \sec\phi.$$

The deformation of area at the central and marginal meridians is defined by

$S_{\lambda=0} = h_{\lambda=0} \cdot k_{\lambda=0}$ and $S_{\lambda=180} = h_{\lambda=180} \cdot k_{\lambda=180} \cdot \cos\theta$, respectively.

The maximal and minimal linear alterations are then represented by the conjugate diameters a and b of an infinitely small ellipse—called the indicatrix—which is produced by an orthogonal projection of an infinitely small circle—circumscribing a point $\left(\frac{\phi}{\lambda}\right)$—from any curved surface upon a plane. These diameters are defined by the relations:

$$a^2+b^2 = h^2+k^2$$
$$a \,.\, b = s = h \,.\, k \,.\, \cos\theta$$

and the maximal distortion of angle (2ω) by

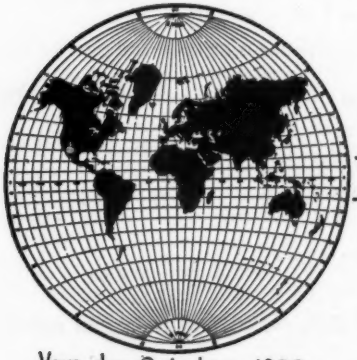
$$\sin\omega = \frac{a-b}{a+b} = \sqrt{\frac{h^2+k^2-2hk\cos\theta}{h^2+k^2+2hk\cos\theta}}.$$

The $y = d\,\frac{3-d^2}{2}$ projection coincides with ours for $d = \frac{\sqrt{5}-1}{2}$; $\theta = 18°$; $\phi = 80°, 46$ (sectio divina).

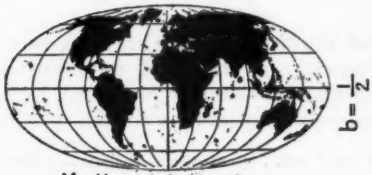
A minimum 2ω value coincides with our minimum θ in a latitude, where we have to surmount the difficulty of fairly representing the most northern parts of the continents of America and Asia ($\phi = 68°$ rot., see table).

5

Mercator 1569



Van der Grinten 1898



Mollweide 1805

Our circular representation can also be considered as a transformation of the two hemispheres into the most natural planisphere, the circumference of which is equal to the circumferences of the two hemispheres combined, so that we always have the superficial area of a globe of half the diameter before our view.

Fig. 5 will serve to compare same with those of Mercator and Mollweide, of which the latter has recently been supplanted by the Aitoff-Hammer "equivalent" projection showing a little improvement in regard to the distortion of angle, leaving it, however, useless for the representation of polar exploration like that of Mercator's "conformal" with the distortion in the opposite direction. Furthermore, Mercator's design was not intended for geographical, but merely for maritime purposes, the loxodromic line appearing as a straight line:

"Nova et aucta orbis terrae descriptio ad usum navigantium emendate accomodata."

6

CONTINENTAL VIEW

AMERICAN VIEW

II.

TABLE OF APPROXIMATE VALUES OF DEFORMATIONS.

y	h	k	Θ	2ω	$S_{\lambda=180}$	$\frac{S\lambda=180}{S\lambda=0}$
Equator			$\phi=0°$ / $\lambda=0°$			
	1,000	1,000	0° 0′	0° 0′	1,000	
			$\lambda=180°$			
$y=\frac{d=0,000}{\frac{c}{2-c}=0,000}$	1,000	1,000	0° 0′	0° 0′	1,000	1,000
	1,000	1,000	0° 0′	0° 0′	1,000	1,000
$c=0,000$	2,000	1,000	0° 0′	38° 56′	2,000	2,000
Arctic and Antarctic Circles			$\phi=66° 33′$ / $\lambda=0°$			
	1,768	2,025	0° 0′	7° 22′	3,580	
			$\lambda=180°$			
$y=\frac{d=0,441}{\frac{c}{2-c}=0,586}$	1,969	2,513	26° 6′	30° 22′	4,443	1,241
	2,568	2,116	15° 40′	19° 20′	5,233	1,462
$c=0,739$	2,967	1,693	0° 0′	31° 42′	5,023	1,403
Minimum 2ω			$\phi=68°$ / $\lambda=0°$			
	1,853	2,109	0° 0′	7° 40′	3,908	
			$\lambda=180°$			
$y=\frac{d=0,458}{\frac{c}{2-c}=0,607}$	2,084	2,670	27° 15′	31° 40′	4,947	1,266
	2,704	2,208	15° 45′	19° 48′	5,743	1,469
$c=0,756$	3,058	1,745	0° 0′	31° 40′	5,336	1,365
Harmonical Relations			$\phi=72°$ / $\lambda=0°$			
	2,083	2,427	0° 0′	8° 44′	5,056	
			$\lambda=180°$			
$y=\frac{d=\frac{1}{2}}{\frac{c}{2-c}=\frac{2}{3}}$	2,406	3,236	30° 0′	35° 32′	7,786	1,540
	3,208	2,517	16° 39′	20° 40′	7,414	1,466
$c=\frac{4}{5}$	3,333	1,942	0° 0′	30° 36′	6,473	1,282
Poles			$\phi=90°$ / $\lambda=0°$			
	∞	∞	0° 0′	13° 35′	∞	
			$\lambda=180°$			
$y=\frac{d=1,000}{\frac{c}{2-c}=1,000}$	∞	∞	90° 0′	180° 0′	∞	∞
	∞	∞	19° 28′	30° 0′	∞	1,000
$c=1,000$	∞	∞	0° 0′	25° 38′	∞	0,500

Art. XXXIX.—*On the Progress of the Albatross Expedition to the Eastern Pacific;* by Alexander Agassiz.

[Extract from a letter to Hon. George M. Bowers, U. S. Fish Commissioner, dated Acapulco, Mexico, February 24, 1905.]

We left the Galapagos (Wreck Bay) for Manga Reva on the 10th of January. On the northern part of this line we did but little work beyond sounding as we were likely to duplicate our former work to the eastward. The fourth day out, in latitude 5° south, we began a series of trawl hauls, surface hauls, and intermediate towings to 300 fathoms. In the northern part of the line to Manga Reva the hauls were remarkably rich as long as we remained within the influence of the western extension of the Humboldt Current, and as long as there dropped from the surface masses of the radiolarians, diatoms and Globigerinæ living in the upper waters. Some of the hauls were remarkable for the number of deep-sea holothurians and siliceous sponges. Among the former I may mention a huge Psychropotes, 55^{cm} long.

As we passed south and gradually drew out of the influence of the western current, we entered the same barren region we passed through to the eastward when going to and from Easter Island. By the time we reached latitude 15° S., the hauls became quite poor; this barren bottom district extended to within a short distance of Manga Reva; corresponding to it we found a most meager pelagic fauna, both at the surface and down to 300 fathoms—so poor that it could afford but little food to the few species, if any, living on the bottom in that region.

We arrived at Manga Reva on the 27th of January and found our collier awaiting our arrival.

While at anchor in Port Rikitea, we examined Manga Reva, the principal island of the Gambier group, from its central ridge on the pass leading from Rikitea to Kirimiro on the west side of Manga Reva, as well as from the pass leading to Taku. On both these passes we obtained excellent views of the barrier reef to the west, north and east of the Gambier Islands, and we could trace in the panorama before us the western reef extending in a northeasterly direction parallel to the general trend of Manga Reva Island for a distance of about 5½ miles.

From the northern horn to nearly opposite Kirimiro Bay the barrier reef has only three small islets; it is narrow, of uniform width, about ⅛ of a mile, plainly defined, submerged in places, and passing north bounds a large northern bight dotted with numerous interior coral patches from a quarter of

a mile to a mile in diameter or length, with from 7 to 11 fathoms. The southern part of the western barrier lagoon off Manga Reva is irregularly dotted with many small patches of reef, with an occasional deep hole of from 15 to 20 fathoms near Manga Reva Island. From the islet to the west of Kirimiro there are but few coral patches, indicating a reef which dips gradually in a distance of a mile to a deep channel of from 4 to 6 fathoms, which separates the northern and western reef from the great reef flat lying to the southwest of Tara Vai. This flat has a width of nearly 2 miles, is about 4½ miles long, and is marked at its southwest extremity by a series of low islets arranged in a somewhat circular line, formed by three deep bays and spurs from the outer line of islets, as so frequently occurs on a wide reef flat in atolls of the Pacific.

This part of the reef is called Tokorua. It shelves very gradually from 3½ to 4 fathoms on the west face to 7, and connects with the plateau upon which stands Tara Vai and Agakanitai. From Tokorua the reef extends in an indefinite narrow ridge 8 miles long, with from 3 to 8 fathoms, in a southeasterly direction. The western edge is steep to, and the eastern face passes gradually into the lagoon, which at that point has a general depth of 8 to 20 fathoms. The deepest part of this region is at the foot of Mt. Mokoto between it and Tara Vai, though Tara Vai is united with Manga Reva Island by a plateau varying in depth from 3½ to 4½ fathoms.

At the southeastern point of the reef it passes into a wide plateau with from 9 to 10 or 15 fathoms. This plateau is about 9 miles wide southwest of Tekava. That part of the atoll has not been well surveyed, so that the position of the reef flat has not been ascertained further west on that part of the east face; but the southeast passage indicates 5½, 6 and 6½ fathoms, where it probably marks the southwestern extension of the eastern barrier reef, separating the lagoon from the southern plateau to the south of the encircling reef.

The western face of Manga Reva and of Tara Vai are indented by deep bays, which are formed by spurs running from the central ridge of these islands, the remnants probably of small craters which flanked the large crater, of which Manga Reva forms the western rim and Au Kena is the remnant of the southeastern edge, the former extension of this rim being indicated by the spits uniting the base of Mt. Duff with Au Kena; and by the projection of Au Kena towards the outer barrier reef, and of the numerous patches of coral reef off the northeast point of Manga Reva towards the outer line of motus until they almost unite with the barrier reef.

The western bays of Manga Reva Island are filled with fringing reefs which leave but here and there a deeper pass to the shore. The south face at the foot of the bluff of Mt. Mokoto and Mt. Duff is edged by a flourishing fringing reef, which extends nearly half a mile on the plateau at their base. The port of Rikitea is a reef harbor formed within the large fringing reef which occupies the whole of the southern bay of Manga Reva Island. The east face of Tara Vai and part of the east and of the west face of Aga-kanitai are also fringed with reefs.

The islets and the islands of Aka Maru, Mekiro, and Maka-pu are within a fringing reef flat which runs around the west face of Aka Maru; Au Kena is also fringed by an extensive reef which runs out in a spit of more than half a mile in a northeasterly direction almost to the outer line of motus, which are nearly united with it by these irregular patches. To the west of Au Kena a huge spit of 2 miles in length extends towards the base of Mt. Duff and almost unites with the fringing reef off the Cemetery, leaving a narrow but deep pass for the entrance of ships into the inner harbor of Rikitea. There is only 1 to 2¾ fathoms of water on these two spits.

The depth of the basin within this area with from 25 to 31 fathoms would be naturally explained as being part of an ancient crater, as in Totoya in Fiji; its northeastern rim is also perhaps further indicated by the comparatively shallow flat of the lagoon to the west of the barrier reef, with from 5 to 11 fathoms of water.

The principal islands of the group are in the central part of the lagoon. The four larger islands are Manga Reva, Tara Vai, Au Kena and Aka Maru. Tara Vai is flanked by Aga-kanitai and another islet to the west called Topunui; Aka Maru is flanked by Mekiro to the north and by Maka-pu to the south. The southeast face of Aka Maru is an extinct crater, of which Maka-pu forms the south rim. The main ridge of Tara Vai is the edge of parts of three craters now opening to the west. The four small volcanic islands in the southern part of the lagoon are isolated fragments, steep to, greatly weathered, and disintegrated. No soundings exist to show their relation to the other islands of the group.

The soundings thus far made indicate in the southern part of the lagoon a depth of about 23 fathoms, with an occasional hole of from 38 to 40, and a gradual slope towards the outer sunken reef. To the south of the old crater of Manga Reva the general depth of the bank varies from 6 to 11 fathoms, with a deeper channel varying from 20 to 40 from southwest of Au Kena towards Tara Vai. The lagoon seems to form a western basin where the depth varies from 10 to 20 fathoms.

To the west of Au Kena and Aka Maru, lying between them and the line of the outer barrier reef islets, a similar but shallower and flat basin exists, off the northern end of Manga Reva, between it and the northern horn of the barrier reef, with from 7 to 11 fathoms. Its rim is formed by a ring of reef patches of varying size.

On two occasions we visited the outer barrier reef and examined the outer line of islets of the eastern face of the Gambier Islands. The position of the islets as marked on the chart is not that of to-day, and the position of the reef flats is not accurate. The position of Tekava and Tauna appears to be correct. Opposite Au Kena and in its extension, the east face of the barrier reefs projects sharply to the east, forming an angular horn with one island south of the horn and the other north, running at sharp angles with it, so as to form a triangle which makes a deep bright opening westward to such an extent that when off the northern side of the horn we could see Tekava far to the westward of it. The second island is followed by a third and then by an island (Tarauru-roa) nearly 2 miles long; these are separated by small gaps. Then comes a larger island (Amou) followed by three small islands separated by deep gaps.

At Vaiatekeue (not the Vaiatekeua on the chart), the reef flat becomes quite narrow; it is hardly more than 100 yards wide; the islets perhaps 50. The northern islets are small and separated by long stretches of low shingle and carry but little vegetation and very few cocoanut trees. There are but two short sand beaches all the way from the northeastern to the eastern horn of the eastern face of the encircling reef of Manga Reva. A regular dam of shingle from 10 to 14 feet high, on the top of which the usual coral reef vegetation flourishes, extends along the outer face of the reef flat, which varies from 50 to 150 yards in width, and is flanked at the base by low buttresses of modern elevated coral reef rock and of breccia in places, all more or less weather beaten and honey-combed.

The islets and their formation and their junction or division into larger or smaller islets and the gaps which separate them, the mode of formation of the buttresses, of the planed-off, hard nearly level reef flat, of the coralline mounds of the outer edge,—all these differ in no way from what has been described in other barrier reef islands and atolls of the Pacific.

The beaches of the lagoon are steep, and corals do not seem to thrive in those parts of the lagoon to which the sea does not have access or at some distance from shore. This is well shown by the vigorous growth of corals in the fringing reef to the south of Mt. Duff on the outer edges of the reef patches of Port Rikitea, and on the spits which connect Au Kena with

Manga Reva, in contrast with those along the west face of the lagoon flats to the west of the eastern barrier reef.

There is a northeast horn of the eastern barrier reef in the extension of Manga Reva Island, forming the northern culmination of the central bight of the eastern face of the barrier reef. From that point the reef flat runs westerly to form the northern horn about 3 miles north of Manga Reva Island. The position of the outer reef cannot be correct on the chart (H. O. No. 2024). On leaving Manga Reva we made three soundings close off the reef flat line of breakers—one off Tekava, at the most $\frac{1}{8}$ of a mile from the reef, in 225 fathoms. Our position, plotted by tangents to the volcanic islands or by their summits, indicated in this case, on the chart, a distance of $1\frac{1}{2}$ miles. A second sounding of 245 fathoms off the eastern horn at less than $\frac{1}{2}$ mile, indicated on chart No. 2024 a distance of 2 miles from the horn; and a sounding of 241 fathoms $\frac{1}{4}$ of a mile off the point which we had visited (Vaiatekeue) indicated a distance of $\frac{3}{4}$ of a mile on the chart.

The slope of the Gambier Archipelago to the east is steep. On coming in sight of Manga Reva we sounded in 2070 fathoms at a distance of 11 miles from Mt. Duff, that is, 6 miles from the outer edge of the reef bearing southwest; and on coming out we sounded again half-way to that point at a distance of $3\frac{1}{4}$ miles from the breakers in 1394 fathoms.

One cannot fail to be struck with the similarity of the Manga Reva Archipelago with the great atoll of Truk. If I remember rightly, Darwin also called attention to this from a study of the charts. Yet, owing to the great size of Truk, no less than 125 miles in circumference, and the great distance of the barrier reef from the encircled volcanic islands, the effect as one steams into Manga Reva is totally different from that produced by Truk. In the latter some of the islands, though large, and of the same height as those of Manga Reva, are much more scattered, and seem of comparatively small importance in the midst of the huge lagoon which surrounds them. The barrier reef islets of Truk are from 11 to 15 miles distant from the encircled volcanic islands. In Manga Reva, which is only 45 miles in circumference, after passing the small islands in the southern and open part of the lagoon when once off Maka-pu, we can fairly well take in the atoll as a whole. The western island (Tara Vai) is only 5 miles off; Manga Reva and Au Kena are about 3, as are also the islets of the east face of the barrier reef; these distances, as you approach the entrance to Rikitea, are constantly growing less, so that when in the gap between Manga Reva Island and Au Kena, at the foot of Mt. Duff, none of the larger islands are more than 3 miles off; and the islets of the eastern face of the barrier reef

are seen to the northeast about 4 miles off. When on the summit of the central ridge of Manga Reva one can, in a radius of a little more than 4 miles, take in the whole panorama of Manga Reva, and get an impression of the relations of its different part far better than can be conveyed by the chart, for the whole of the visible part of the archipelago is included in a line drawn east and west, south of Maka-pu; south of that line the position of the southwestern reef can be traced only by the discoloration of the waters.

Manga Reva is an intermediate stage of erosion and denudation, between a lagoon archipelago such as Truk, and a barrier reef island like Vanikoro, and other islands in the Society groups such as Bora Bora,* Huaheine, Raiatea, Eimeo, in which the surrounding platform has comparatively little width and the barrier reef is close to the principal island and often becomes part of its fringing reef. Manga Reva is open to the south and to the west, Vanikoro to the east, while the volcanic islands of Truk are completely surrounded by the outer encircling barrier reef, as are the Society Islands just mentioned, which have several wide passages into the lagoon through the wide barrier reef.

One is tempted to reconstruct the Gambier Archipelago of former times and to imagine it with a great central volcano, of which Manga Reva and Au Kena are parts of the rim which once were connected from the southeast point of Manga Reva to Au Kena, and thence along the line of the outer islets to the northeast end of the former island with a deep crater of more than 34 fathoms. On the west face it was flanked by smaller craters extending to the western islets of the barrier reef, of which the bays of Taku, Kirimiro and Rumaru, and the bays of the west side of Tara Vai are the eastern ridges. There were probably also other secondary volcanoes, of which Aka Maru and the islets of the south part of the lagoon are the remnants, the latter all being situated on the gentle slope of the southern part of the Manga Reva plateau; this may have been the southern slope of the principal volcano of the group, on the face of which have grown up the outer lines of the barrier reef and its islets.

The existence of a large central volcano would readily explain the depth of the lagoon in its different regions, as well as the great depth off the outer face of Manga Reva, depths showing slopes which are no steeper nor more striking than the height and slopes of the southern part of Manga Reva or Tara Vai, of Aka Maru, and of Maka-pu, supposing them to be extended into the sea.

*See A. Agassiz,—The Coral Reefs of the Tropical Pacific, Plates 210 and 231.

Mt. Mokoto and Mt. Duff drop precipitously for more than one-third their height and in less than a quarter of a mile fall from over 1300 feet to the level of the sea. Similar slopes are found along the volcanoes of Easter Island where there are no coral reefs. The edge of the crater of Rana Kao drops perpendicularly a height of nearly 1000 feet in less than one-eighth of a mile horizontal distance; and the eastern face of the crater of Rana Roroka rises vertically about 800 feet above the plain of Tangariki.

It is interesting to note how poor is the flora of the Manga Reva Archipelago as compared with that of the more western volcanic islands like the Marquesas and the Society Islands and some of the western elevated Paumotus. In the Gambier Archipelago the forests are reduced to a few patches extending along the small valleys of the slopes of the volcanic spurs. I am informed that even in the thirties of the last century, when the missionaries first landed at Manga Reva, the forest trees, while more numerous, yet never attained the luxuriance of growth that they attain in the Society and Marquesas Islands. At the present day, with the exception of the forest patches just mentioned and a few trees which have been introduced for cultivation, the islands of the group are in great part thickly covered with a species of cane closely resembling that of our Southern States. The fauna of Manga Reva is also extremely poor. There are no mammals, and with the exception of a "sandpiper" no indigenous birds. Sea birds are few in number, and in our trip in the Eastern Pacific we rarely had more than three or four birds accompanying us; often only one, and frequently none was visible for days. There are a few lizards on the islands, apparently of the same species as those in the Society Islands.

We left Port Rikitea for Acapulco on the 4th of February to anchor off Aka Maru; on the 5th we left our anchorage, sounded off the east face of Manga Reva, and took photographs.

On our way north from Manga Reva to Acapulco we did not begin to trawl or tow until warned by the surface nets that the surface was becoming richer in animal and vegetable life and also by the surface temperatures indicating that we had reached the southern edge of the cold western equatorial current. A little north of 10°, south latitude, we made our first haul and deep tow, and found a very rich fauna down to the 300 fathom line, recalling the pelagic fauna of the eastern lines and fully as rich. On trawling we found, as we expected, a very rich bottom fauna.

Among the animals brought up in the trawl there were some superb Hyalonemas, siliceous sponges, Benthodytes and

other deep-sea holothurians, fine specimens of Freyella, and some large ophiurans. This haul is interesting as showing that in the track of a great current, with abundance of food, we may find at a very considerable depth (2422 fathoms) an abundant fauna at very great distances from continental lands. We were, at this station, about 2140 miles from Acapulco, 1200 miles from Manga Reva, 1700 miles from the Galapagos, and about 900 miles from the Marquesas.

Another haul made under the equator near the northern edge of the cold current in 2320 fathoms gave us the same results. The pelagic fauna was very abundant, the surface teemed with radiolarians, diatoms, and Globigerinæ and swarmed with invertebrates. The trawl contained a superb collection of bottom species of holothurians, Brisinga, Hyalonema, Neusina, and on this occasion we brought up the only stalked crinoid collected during this expedition—parts of the stem of two specimens of Rhizocrinus, of which, unfortunately, the arms were wanting.

Our progress, which was excellent during the first days of our journey after leaving Manga Reva, has for the past six days been greatly impeded by head winds in the region where we ought to have been in the full swing of the southeasterly trades. This led us to abandon with great reluctance all idea of further work in the equatorial belt of currents; to give up our proposed visit to Clipperton, and on account of our limited coal supply, to make for Acapulco, merely sounding every morning. This was a great disappointment to me, as we had every reason to expect to be able to spend some time in the region of the equatorial current's belt and settle more conclusively than we have been able to do the question of their influence upon the richness of the fauna living in their track far from continental shores or insular areas.

The presence of diatoms in all parts of the Humboldt Current, which we crossed from south of Callao to the equator at the Galapagos and west towards Clipperton, shows how far the track of a great oceanic current can be traced, not only by its temperature but also by the pelagic life within or near it. When once in the warm westerly equatorial current the diatoms disappear and the bottom samples show only surface radiolarians and Globigerinæ.

We took a number of serial temperatures in the line Galapagos to Manga Reva, passing from the colder water of the Humboldt Current to the warmer waters south toward Manga Reva. The temperatures at 200 fathoms became nearly identical. North the great change in temperature took place between 25 and 200 fathoms, where there was a difference of 24°. South the warm water extended 100 fathoms, a great change occurring

between 100 and 200 fathoms, a drop of 16°. The serial temperatures taken at the southern and northern edges of the cold current on the line Manga Reva-Acapulco agreed well with those taken in the same current to the east.

The samples of the bottom obtained by the soundings taken by the expedition or gathered in mud-bag and in trawl indicate that an immense area of the bottom of the Eastern Pacific is covered with manganese nodules, and that they play an important part in the character of the bottom, not only in the area covered by this expedition; the area of manganese nodules probably extends to the northwest of our lines to join the stations where manganese nodules were found by the Albatross in 1899 in the Moser Basin, on the line San Francisco to Marquesas.

This area may also extend south of our lines Callao to Easter Island, and join the line west of Valparaiso where the Challenger obtained manganese nodules at many stations. I do not mean to imply that manganese nodules are present to the exclusion of radiolarians and of Globigerinæ. It is probable that the layer of nodules are partly covered by them, and by the thick, sticky, dark chocolate-colored mud which is found wherever manganese nodules occur.

During this expedition we sounded every day while at sea and developed very fairly that part of the Eastern Pacific which lies to the south and west of the line from Cape San Francisco to the Galapagos and west of a line from Galapagos to Acapulco, limiting an area occupied by the Albatross in 1891. The area developed by us is included by a line 3200 miles in length from Acapulco to Manga Reva and the area north of a line from Manga Reva to Easter Island and from Easter Island to Callao. We developed on our line Galapagos to Manga Reva the western extension of the Albatross Plateau, and found it of a depth varying from 1900 to somewhat less than 2300 fathoms in a distance of nearly 3000 miles; about half-way from the Galapagos to Manga Reva we came upon a ridge of about 200 miles in length with a depth of 1700 to 1055 fathoms, dropping rapidly to the south to over 1900 fathoms. I propose to call this elevation Garrett Ridge.

Our line from Manga Reva to Acapulco continued to show the western extension of the almost level bottom of the Eastern Pacific. In a distance of 3200 miles the depth varied only about 400 fathoms. This great area was practically a mare icognitum. Three soundings in latitude 20° south towards the Paumotus and five soundings in a northwesterly trend from Callao to Grey's Deep, are all the depths that were known previously of this great expanse of water. This existence of the great plateau dividing Barber Basin along the South American coast from Grey and Moser Basins to the west is most interest

ing. It recalls the division of Southern Atlantic into an Eastern and Western Basin by a central connecting ridge, the Challenger ridge. The Albatross Plateau joins the western extension of the Galapagos Plateau as developed by the Albatross in 1891.

The existence of a sounding of 2554 fathoms near the equator in longitude 110° west would seem to indicate a small basin included in this plateau disconnected from Grey's Deep and Moser Basin by its extension to the west. How far west towards these basins that extension reaches, no soundings indicate as yet. It is interesting to note that along the Mexican coast there are a number of deep basins lying disconnected close to the shore just as there are a number of disconnected deeps close along the South American coast extending from off Callao to off Caldera, Chili, opposite high volcanoes or elevated chains of mountains. These basins and a great part of the steep Mexican continental shelf are deeper than the Albatross Plateau to the south, and form a deep channel, separating in places the Plateau from the steep continental slope. The steepness of the continental shelf is well seen, especially off Acapulco and Manzanilla. One of the small basins along the Mexican coast with 2661 fathoms lies off Sebastian Viscaino Bay; another with more than 2900 fathoms is to the west of Manzanilla Bay; a third to the southeast of Acapulco has about the same depth, and a fourth with 2500 fathoms is off San Jose, Guatemala. Our last soundings off Acapulco about 29 miles south of the lighthouse, in 2494 fathoms, showed the western extension of one of these deep holes to the east of Acapulco. These basins off the west coast, close to the shore at the foot of a steep continental slope, are in great contrast to the wide continental shelves which characterize the east coast of Central America and the east coast of the United States.

The collections made during the present expedition will give ample material for extensive monographs on the holothurians, the siliceous sponges, the cephalopods, the jelly-fishes, the pelagic crustaceans, worms and fishes of the Eastern Pacific, as well as on the bottom deposits and on the radiolarians and dinoflagellates, diatoms, and other protozoans collected by the tow nets. Small collections of plants were made at Easter Island and Manga Reva which may throw some light on the origin and distribution of the flora of the Eastern Pacific.

Art. XL.—*Note on the Names Amphion, Harpina, and Platymetopus;* by Percy E. Raymond.

After my recent paper on the Chazy Trilobites (Annals Carnegie Museum, vol. iii, No. 2) was in type, Dr. W. J. Holland called my attention to the fact that the name *Amphion* was in general use for a common genus of moths. A little investigation showed that not only *Amphion*, but *Harpina* and *Platymetopus*, two other generic names used in the paper cited, were likewise preoccupied.

The first use of *Amphion* as a generic name was by Hübner, who, in 1816, applied it to one of the Lepidoptera.* Pander proposed the same term for a tribobite, in 1830,† and designated *Amphion frontiloba* = *Asaphus Fischeri* Eichwald as the type. Since *Amphion* is thus preoccupied, it becomes necessary to find some other name to apply to this trilobite. Angelin, in 1854,‡ used *Pliomera* as a new generic designation for trilobites of the type of *Asaphus Fischeri* Eichwald, evidently intending to restrict the genus to its original meaning. This name *Pliomera* should now be adopted to replace the preoccupied name *Amphion* Pander.

The Chazy species *Amphion canadensis* differs in several particulars from the European form *Pliomera Fischeri*. In the American species the median furrow of the glabella is very faint and frequently absent; the second pair of furrows are much further apart, thus producing one large frontal lobe instead of two small ones as in the Russian species; the facial sutures reach the lateral margin in front of the genal angles; the frontal border is not denticulate, and the two species do not have the same number of thoracic segments.

The absence of the median glabellar furrow and of the denticulate margin seem to be of considerable taxonomic importance, as this furrow cannot be regarded as due to the mechanical effect produced by the enrollment of the animal in pressing the spinose tail against the glabella. This is proved by the fact that no pygidial spine is situated opposite the median furrow, but that the two median spines of the pygidium are placed so that one comes on either side of the frontal furrow. Again, the second pair of glabellar furrows are longer than this median furrow, and the third set is still longer, as would be the case if all were glabellar furrows. Finally, in *Amphion canadensis* there is a smooth border around the front, and the median indentation is almost obsolete, while the pygidium

* Verzeichniss bekannter Schmetterlinge.
† Beiträge zur Geognosie des russischen Reiches, p. 139.
‡ Palæontologica Scandinavica, p. 30.

is exactly similar to that in the European species. If this median indentation does represent the first pair of glabellar furrows, and *Amphion canadensis* has lost it and the denticulate glabellar margin as well, then *Pliomera Fischeri* denotes an earlier stage in the development, and it will probably be best to separate the American forms under the name *Pliomerops*, with *Amphion canadensis* as the type. *Amphion convexus* Billings and *Amphion Westoni* Billings appear to belong to this subgenus. In regard to *Amphion Barrandei* Billings states that a small median pit is present in exfoliated specimens,* indicating the presence of this median furrow in a rudimentary but deep-seated condition.

The generic term *Harpina* was first used by Burmeister, in 1844, for a species of Coleoptera,† while Böck used it for a crustacean, in 1870.‡ Novák proposed the name a third time, in 1884, for a subgenus of *Harpes*,§ using it to designate the Lower Silurian forms of the genus. The hypostoma differs in the Upper and Lower Silurian species, and it was on this difference that the two genera were separated. The hypostomas of the Chazy forms are not known, but it is probable that they will be found to agree with those of the species from the Ordovician investigated by Novák. In any event, it is necessary to supply a new name in place of the preoccupied *Harpina*, and *Eoharpes* is herewith suggested.

Platymetopus was first used by Dejean, in 1829, for a species of Coleoptera,‖ and by Angelin, in 1854, for a subgenus of *Lichas*.¶ In 1902, Reed** saw that the name was preoccupied and suggested *Paralichas* to take its place. Unfortunately this name had been applied by White, in 1859, also for a species of Coleoptera,†† hence it will be necessary to give a new name for species of Division 3 of Schmidt, of which *Lichas lævis* Eichwald is the type.‡‡ For this purpose, *Amphilichas* is proposed, and should be applied to the Chazy species now known as *Platymetopus minganensis*.

Paleontological Laboratory, Yale University Museum, March 23, 1905.

* Paleozoic Fossils Canada, pp. 288, 321, 322.
† Handbuch der Entomologie. ‡ Overs. Dan. Selsk.
§ Studien an Hypostomen der böhm. Trilobiten, No. 2, p. 4.
‖ Species général. des Coléoptéres, vol. v, p. 815.
¶ Palæontologica Scandinavica, p. 68.
** Quart. Jour. Geol. Soc. London, vol. lviii, pp. 62, 89.
†† Ann. Mag. Nat. Hist., ser. 4, vol. iii, p. 284.
‡‡ Rev. der Ostbalt. Silur. Tril. Mém. Acad. Imp. St. Petersbourg, ser. 7, vol. xxxiii, No. 1, p. 49.

ART. XLI.—*The Bragdon Formation;** by J. S. DILLER.

Introduction.—The Bragdon formation of Shasta and Trinity counties, California, was named by Mr. O. H. Hershey† and regarded by him as Jurassic. The first fossils found‡ by my party tended to confirm his view, but later§ upon structural grounds it was referred provisionally to the lower part of the Carboniferous. This called forth an article‖ from Mr. Hershey maintaining at length his original views. Last summer other fossils were discovered in the Bragdon confirming its reference to the Carboniferous, and this article is intended to present the evidence.

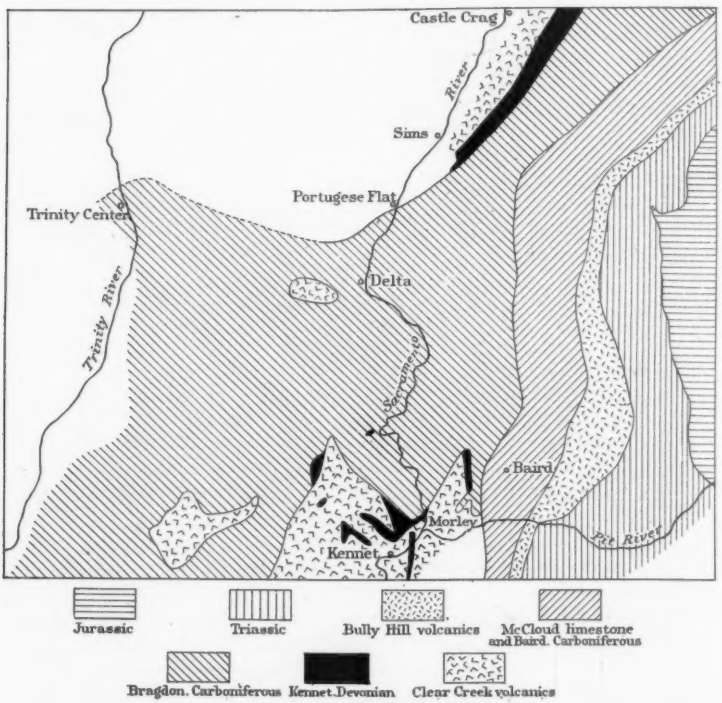
Lithological character.—The Bragdon formation was designated by Mr. Hershey¶ to include an extensive series of thin-bedded shales, sandstones and conglomerates lying some miles north and northwest of Redding in Shasta and Trinity counties, California. The dark, often black, shales in strata ranging from a foot to sixty feet in thickness alternate with thin beds of sandstone and conglomerate. The sandstones are usually normal although sometimes dark, hard, and flinty, like quartzite and occasionally tuffaceous, but as Hershey says, and I fully agree, "the conglomerates are the most characteristic portion of the series."**

They are generally composed in large part of black and gray pebbles of quartz with others of sandstone, shale and limestone. Generally they contain no igneous material, but in some places it becomes abundant. By weathering, the limestone pebbles disappear leaving holes upon the surface, thus giving to the conglomerate a peculiar porous aspect. The beds of conglomerate are usually less than ten feet in thickness, but sometimes attain a maximum of nearly fifty feet. Quartz and chert pebbles prevail in the smaller and finer beds and sometimes also in the larger beds where the pebbles are not over half an inch in diameter. As the beds become coarser pebbles of sandstone become most abundant, while those of limestone also generally increase in number and size.

The Bragdon conglomerate is most abundant along the Sacramento River. Much of it is fine but some of it is coarse, with one exception much coarser than that found elsewhere. It is best exposed three-fourths of a mile above Elmore and also

* Published by permission of the Director of the U. S. Geological Survey
† Am. Geol., vol. xxiv, p. 39, and vol. xxvii, p. 236.
‡ U. S. Geol. Survey, Bull. 196, p. 65.
§ This Journal, vol. xv, p. 351.
‖ Am. Geol., vol. xxxiii, pp. 248 and 347.
¶ Am. Geol., xxvii, p. 236.
** Am. Geol., vol. xxxiii, p. 252.

half a mile above the mouth of Middle Salt Creek; in both cases upon the left bank of the river, and sandstone cobbles predominate. They are thoroughly waterworn, round and smooth, attaining at the first locality a maximum diameter of two feet although they are generally not over six inches. Limestone cobbles are less abundant, somewhat smaller and



Scale of map, 1 inch = nearly 7 miles.

often fossiliferous, while pebbles and coarse sand chiefly of vein quartz and chert form the matrix between the larger fragments as well as the beds of finer conglomerate. Away from the river, coarse conglomerate is rare. It was noted on the divide, about one and one-fourth miles southwest of High Mountain, called also Nawtawakit Mountain, close to the eastern edge of the Bragdon, where the pebbles of gray sandstone weathering red are sometimes six inches in diameter and very hard.

Distribution.—The principal area of the Bragdon, and the one to which, excepting the western border, I have given special attention, is what Mr. Hershey calls the "eastern or

type area."* As shown upon the accompanying map, it is roughly pear-shaped, constricted in the small part with the longer axis running nearly northeast and southwest. The bigger end lies near Trinity River from Lewiston to Trinity Center, while the smaller end is trenched by the Sacramento from Portugese Flat to Morley, and the long broad stem runs northeast from North Salt Creek to the McCloud, a total length of fifty miles and maximum breadth of about twelve miles. The borders are locally irregular and there are a few small outlying masses of Bragdon, but in general this area is remarkable for its continuity from the Trinity River to the McCloud without interruption excepting a small area of Devonian on Little Sugar Loaf Creek and small areas of volcanics on Clear Creek and Dog Creek, as well as several long narrow masses, not shown on the map, east of the Sacramento River. The smaller end of the Bragdon area, including the stem lying east of the Sacramento, is bordered on the one hand by the Carboniferous sediments and on the other by those of Devonian age; but west of the Sacramento, excepting a small bit on Backbone Creek, the type area of the Bragdon is everywhere bounded by igneous rocks, some volcanic, others plutonic. It is evident, I think, that the region of greatest promise in studying the taxonomy of the Bragdon is east of the Sacramento, where it comes in contact both above and below with sediments whose horizon is well established by an abundance of fossils. West of the Sacramento we are adrift among a plexus of igneous rocks whose exact age in most cases is not easily determined.

Stratigraphy.—The Bragdon, composed as it is of thin beds, lacks a definite rigid horizon to resist folding. It is easily crumpled, giving a great variety of dips and strikes. In the part of the area east of the Sacramento the dips are sometimes vertical, but for the most part not over sixty degrees, often under thirty and generally to the eastward, and agree fully with the general position of the Jurassic, Triassic and definitely known Carboniferous (McCloud and Baird), all of which lie to the eastward and increase in age westward, suggesting that the Bragdon is the oldest and lies beneath the Baird. This view is strengthened by an examination of the eastern limit of the Bragdon where it adjoins the Baird. The limit may be traced for more than twenty-five miles parallel with the Baird and McCloud limestone, within a mile or two west of the latter, and is marked by the disappearance of the characteristic Bragdon conglomerate. It must not be supposed that the same bed of conglomerate can be traced continuously along the eastern edge of the Bragdon for twenty-five miles. The conglomerate is in thin lenticular beds with traceable continuity of

* Am. Geol., vol. xxxiii, p. 251.

only a few miles, but farther along in the same horizon the conglomerate comes in again. This top horizon of the Bragdon will be noted at only two points. On Hirz Creek road the top conglomerate is fine, but west of it a few hundred feet is another that is coarse with fossiliferous Devonian pebbles. The strata are all nearly vertical and for the most part well exposed eastward to the shales full of Baird fossils. On the divide about a mile and a half southwest of High Mountain the characteristic conglomerates are well developed. Most of them are fine, but one is coarse, with many pebbles of sandstone and some of fossiliferous Devonian limestone. These lenses of Bragdon conglomerate are immediately and conformably overlain by sandstone containing Baird fossils. An observer cannot carefully study the contact of the Baird and Bragdon from one end to the other without being convinced on structural grounds alone that the Bragdon and Baird are conformable and that the former is the older.

As to the lower limit of the Bragdon, the matter is more complex owing to the fact that the basement on which it rests is variable, sometimes sedimentary rocks of Devonian age, but more frequently volcanics. The best exposure of the Bragdon resting on the Devonian is along Backbone Creek, three and one-half miles north of Kennet, where over 800 feet of Devonian shales and limestone* are overlain unconformably by a thirty-foot bed of Bragdon conglomerate containing fossiliferous Devonian fragments. To the east and west of this locality the Bragdon beds overlap the Devonian to the volcanics, but in both directions there soon appear other patches of Devonian lying between the Bragdon and the volcanics. Nearby, on Little Sugar Loaf Creek, a small area of fossiliferous Devonian is completely surrounded by Bragdon. Along this portion of the Bragdon border the small areas of Devonian are remnants left by pre-Bragdon erosion of a once continuous sheet of Devonian and thus exposing the volcanic rocks which lie beneath and were erupted before the Devonian sediments were deposited. To the northward, in the vicinity of Hazel Creek, the Devonian shales and limestone areas are more continuous and may be traced for over ten miles along the western border of the Bragdon. Although the contact is not well exposed, the fact that the basal conglomerates of the Bragdon are at least generally, if not everywhere, composed wholly of debris from the Devonian sedimentary rocks, clearly indicates an unconformity by erosion between them.

It is in this portion of the pear-shaped Bragdon area that its taxonomy is most evident and may be conveniently studied along the trails from the McCloud to Castle Crag and Sims on

* This Journal, vol. xv, p. 347.

the Sacramento. The essential part of the McCloud-Sims section is given below, beginning with the newer beds on the east. The thickness given is only a rough estimate, making allowances for repetition by many small folds and faults.

Carboniferous,	limestone, (McCloud)	2000
"	reddish shales and sandstones with much volcanic material (Baird)	1000
"	shales, sandstones and tuffs with siliceous conglomerates (of Devonian pebbles) increasing in number and size from the top towards the bottom (Bragdon)	2900
	(Unconformity)	
Devonian,	dark shale	100
"	limestone	150
"	black slaty shales (scarcely any chert)	400
?	volcanic series	

Relation of the Bragdon to Volcanic Rocks.—The Redding quadrangle contains an extensive series of highly fossiliferous sediments from the Devonian to the Tertiary inclusive, and affords one of the most complete records of the volcanic phenomena of that interval to be found in the state of California. This is not the place to enter into details concerning this record, and yet it is necessary to consider it very briefly in a general way to elucidate the relations of the Bragdon. Devonian sediments show the existence of andesitic and rhyolitic lavas of earlier date, and during the Bragdon and especially the earlier portion of the Baird there was considerable volcanic activity which continued for a long time and culminated about the close of the Paleozoic. A great sheet of lava and tuffs was formed at that time which appears between the Carboniferous and Triassic sediments. Volcanic eruptions continued at intervals throughout the Triassic and Jurassic but during the Cretaceous there was a long interval of quiescence, followed by the great eruptions of the Tertiary. It is not to be supposed that volcanic products were in all cases spread equally over the whole Klamath Mountain area for each volcanic horizon. The eruptions were local, yielding large masses at different places at different times, and to establish the horizon of each it is generally necessary to determine their relation to fossiliferous sediments.

Older than the Miocene, one of the largest among half a dozen horizons of volcanic products in the Redding quadrangle is that on the border of the Paleozoic and Mesozoic. The andesitic and rhyolitic lavas and tuffs of that horizon form a prominent ridge to which Bully Hill belongs, and the whole mass may be conveniently referred to as the "Bully Hill volcanics." Con-

cerning the age and structural relations of the Bully Hill volcanics, all observers practically agree in placing them about the close of the Paleozoic and the beginning of the Mesozoic, but as to the age of the large area of volcanics southwest of Bully Hill, along the Sacramento—the rocks which Mr. Hershey has called his Clear Creek volcanic series, I have but recently come to a definite conclusion. The generally complete absence of volcanic material in the typical Bragdon conglomerates, and also the fact that much of the igneous material which appears in the areas of "Clear Creek volcanics" cuts the Bragdon, for a long time counterbalanced in my mind the contention of Hershey that the Bragdon is younger than the "Clear Creek volcanic series" and rests directly upon it. But the discovery of andesitic and rhyolitic material like that of the Clear Creek series in certain Bragdon conglomerates well characterized by fossiliferous pebbles of Devonian limestone, leaves no doubt that in the main the "Clear Creek volcanics" near the Sacramento are, as Hershey maintains, older than the Bragdon.

On Backbone Creek, several miles above Kennet among the stratified rocks which appears to belong to the Devonian, there are definite beds of volcanic debris which indicate that andesites and rhyolites, like those of the "Clear Creek volcanics," were exposed to furnish Devonian sediments. The relation of the Devonian limestone and shales in the Kennet region to the "Clear Creek volcanics" confirms the same view. The Devonian sediments appear in patches completely surrounded by the "Clear Creek volcanics," at first suggesting that the Devonian sediments are broken up and enclosed by the volcanics. On closer examination, however, the isolated patches of Devonian are clearly seen to be, for the most part, remnants of a once continuous but deformed sheet of Devonian that covered the "Clear Creek volcanics" of that region, and was cut up by pre-Bragdon erosion into separate patches exposing larger areas of the underlying volcanics. A few miles northwest of Kennet the Devonian patches lie on ridges completely separated by the narrow canyon of Little Backbone Creek, but on Backbone Creek erosion has not yet quite completed the separation of the Devonian masses upon its sides.

The "Clear Creek volcanics" of the Kennet area which are beneath the Devonian, Mr. Hershey regards as on top of the Devonian. If his view were correct, they should lie between the Bragdon and the Devonian, which is certainly not true in the Kennet region where all three are well exposed, and in every Devonian outcrop touched by both Bragdon and "volcanics" the former is on top and the latter beneath. This relation is clearly exposed at two points on Backbone Creek, also on Little Sugar Loaf Creek, at the head of Bailey Creek,

four miles west of Baird and near the mouth of Hazel Creek. It is evident, therefore, that the "Clear Creek volcanics" of Hershey in the Kennet region, being earlier than the middle Devonian, are not equivalent to the Bully Hill volcanics of late Carboniferous and early Triassic age. The fossiliferous tuffs and shales which are interstratified with the lavas of "Bully Hill volcanics," showing them to be of submarine eruption, are entirely lacking in the "Clear Creek volcanic series."

The general statements made in this paper apply only to the type areas of the Bragdon and of the "Clear Creek volcanics" east of Trinity Mountain, where it is believed their normal relations to Carboniferous and Devonian are better exposed than anywhere else in the Klamath Mountains.

Age of the Bragdon.—The Bragdon formation is regarded by Hershey as Jurassic about the horizon of the Mariposa, and he has set forth his evidence in detail.* It is in part lithological but largely structural, in which much stress in laid on the relative position of his "Clear Creek volcanics" regarded as of early Triassic age, but which, as I have already shown, are in part, at least, earlier than the middle Devonian.

Upon a geological map of portions of the copper belt of Shasta County, Anderson† represents the same rocks as Triassic, but the circumstances of publication did not permit him to present the evidence.

A study of the areal distribution of the Bragdon and its stratigraphic relation to the Carboniferous and the Devonian led me several years‡ ago to refer it provisionally to the lower part of the Carboniferous. Further field study has confirmed me in that opinion as already set forth. Fossils recently discovered support the same conclusions and will now be considered.

Mr. James Storrs, who has collected most of the fossils for my party of the Geological Survey in the Redding Quadrangle, early discovered that some of the limestone fragments of the Bragdon conglomerate are fossiliferous. Fossils have been collected at various times during four years from the conglomerate pebbles at twenty-one localities, chiefly along the Sacramento and to the eastward close up to the outcrop of the Baird formation, but also to the westward as far as Trinity Mountain and on the northwest to within a few miles of Trinity Center. These fossils were referred at first to Mr. Schuchert and later to Dr. Girty, and all of them as far as determinable, with one possible exception found on Bailey Creek to be mentioned later, were

* Am. Geologist, vol. xxxiii, pp. 248–256 and 347–360.
† State Mining Bureau, Bull. 23, 1902, on Copper Resources of California.
‡ This Journal, vol. xv, p. 352.

reported as Devonian like those already known in the region. The Devonian fossils in the pebbles simply show that the conglomerate is later than the Devonian.

Careful search was made in the paste of the conglomerate as well as in the associated sandstones and shales for fossils of the Bragdon epoch. Fossils were found in eleven localities, enumerated below, at six of which the fossils are in shales and sandstones, associated with the characteristic Bragdon conglomerate, while at the other five the fossils occur in the paste of the conglomerate, but not in the pebbles.

One of the most important occurrences is upon the divide southwest of High Mountain, where the sandstones conformably interbedded with characteristic Bragdon conglomerate contain shells which Dr. Girty reports as "Paleozoic, and without much doubt early Carboniferous, related to the Baird." The fossils, among which is a large "Spirifer of the Striatus type," occur in several beds. The exposures are good and leave no doubt that the fossils are of the Bragdon horizon.

Perhaps the most important locality is beside the railroad, one and one-half miles northeast of La Moine, where fossils were found in the sandstone adjoing the Bragdon conglomerate. From this locality Dr. Girty reports *Schizodus* sp., *Loxonema* sp., *Pleurotomaria*? sp. and *Straparollus* aff. *S. luxus*. There is no room for doubt that these fossils belong to the Bragdon and are not derived from an older formation, and Dr. Girty remarks that if this be admitted "no other conclusion is possible than that the Bragdon is a Paleozoic formation. Indeed it is fairly safe to say that the horizon is not later than Baird, for the local faunas have many points of resemblance with that of the Baird, and none at all with those of the overlying Carboniferous formations."

From the shales about two and one-half miles southwest of the mouth of Hirz Creek, and also from shales in an isolated patch of the Bragdon about one and one-fourth miles a little east of south from Bayha, Cephalopods were collected. From the first locality Dr. Girty reports *Glyphioceras*, and from both a form "of what seems to be a *Nautiloid* to which Mr. Stanton recalls nothing similar in the Mesozoic and which is not out of place in the Carboniferous." Dr. Girty states further that "The little *Goniatite* shows only the course of the suture lines, external characters being concealed. The sutures remind me much of those of the *sphæricus* group of *Goniatites* (*Glyphioceras*), and if this is truly the relation of the specimen the age would probably be late Lower Carboniferous. Prof. J. P. Smith, who examined the specimen, on the other hand, thinks that it might represent an immature stage of an *Ammonite*. It seems to me, however, that an

Ammonitic stage sufficiently immature to show sutures of the simplicity of the present example would be of a size much smaller than it possesses. In my opinion, therefore, the specimen is a *Glyphioceras*, but the possibility should not be lost sight of that it may be a young stage of a more complicated and later developed type."

We now come to the fossils found in the paste of the Bragdon conglomerate. Dr. Girty identifies *Lithostrotion sublaeve*, a Baird species, from one and one-half miles east of Portugee Flat, and also on O'Brien Creek, one-fourth mile below the stage road. No other fossils were found at either place.

On Hazel Creek, six miles east of Sims, there is a conglomerate composed largely of volcanic material with but little chert and therefore not typical Bragdon. It includes what look like fragments of rotten calcareous sandstone which readily disintegrates, leaving very distinct and complete impressions of delicate parts of corals against the paste in such a way as to indicate, as pointed out by Dr. Girty, that the fossils are in place and not derived. Dr. Girty recognizes from this locality *Zaphrentis* sp. and *Loxonema* sp., and the last, if not both, appears to belong to the Baird.

The only case in which there is reasonable doubt concerning the relations of the fossils has already been referred to. It is on Bailey Creek, where a Bragdon conglomerate contains *Zaphrentis* and *Loxonema*? in moderately soft sandstone having the form of a small pebble, while there is a suggestion in the arrangement of the fossils that, as on Hazel Creek, they are contemporaneous, yet the evidence is not clear. If it is a pebble, two explanations may be offered. There is the possibility and perhaps probability on the one hand that the forms mentioned may have begun in the Devonian, and from thence have been derived, or, on the other hand, that they may not be the identical forms of the Baird.

In estimating the weight of the evidence afforded by this one doubtful pebble containing more or less questionable forms, it is necessary to remember that the fossils in the sandstones and shales, as well as the matrix of the Bragdon conglomerate, point definitely to the conclusion that the Bragdon formation is Paleozoic and is fully in harmony with the stratigraphic evidence which places the Bragdon at the base of the Carboniferous section conformable beneath the Baird.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Preparation and Properties of Tantalum.* — Metallic tantalum has been prepared by Berzelius, Rose, and more recently by Moissan, but always in an impure condition, either as a black powder, or, in Moissan's case, as a very hard, brittle substance containing carbon. Werner von Bolton has recently succeeded in obtaining tantalum in a practically pure condition, and finds that it possesses some very remarkable properties which promise to make the metal one of great practical importance. Von Bolton has improved the processes of Berzelius and Rose (where a double fluoride is reduced with an alkali metal) and he has purified the product further by fusing it in a vacuum by means of the electric arc. He has also applied an interesting electrolytic process, consisting in passing an electric current through slender rods of the lower oxide in a bulb similar to that of the incandescent lamp, meanwhile pumping away the oxygen formed by the electrolysis as fast as it was formed. Pure tantalum when fused forms a brilliant regulus having a platinum-gray color, which can be hammered and drawn out into the finest wire. The specific heat is ·0365, and the atomic heat, 6·64, corresponds to Dulong and Petit's law. The specific gravity of the cast metal is 16·64. Its melting point was found to be 2250 to 2300°, and is far above that of platinum. It remains brilliant upon exposure to air, and oxidizes slowly when heated in air or oxygen. The metal shows an extraordinary combination of the properties of malleability, ductility, tenacity and hardness. For instance, when a red hot piece of tantalum is put under the steam-hammer, a plate of the metal is readily formed, which, when repeatedly heated and hammered, attains a hardness equal to the diamond. An attempt to bore such a plate one millimeter thick with a diamond drill with 5000 revolutions per minute had to be abandoned after three days and nights of continuous work, as a depression of only one-quarter millimeter was made thereby, and the diamond drill was much injured; still the plate could be made thinner by rolling, without losing its hardness. Many applications are predicted for this most wonderful metal, one of which is the use of the wire for the incandescent lamp, in which it gives more than double the efficiency of the carbon thread.—*Zeitschr. für Electrochem.*, xi, 46. H. L. W.

2. *Gravimetric Determination of Nitric Acid.* — M. Busch has synthesized a base, diphenyl-endanilo-dihydro-triazol, named "Nitron" for the sake of brevity and for commercial purposes, which forms a very insoluble, stable nitrate, and, therefore, furnishes a means for the direct gravimetric determination of nitric acid, as well as for its qualitative detection. The reagent is manufactured on a commercial scale by Merck, and is employed

in the form of a ten per cent solution in five per cent acetic acid. For qualitative tests five or six drops of the reagent are added to 5 or 6^{ccm} of the liquid to be tested, after the latter has been acidified with a drop of dilute sulphuric acid. A white, voluminous precipitate appears immediately when considerable quantities of nitric acid are present, while with minute quantities of the acid small, brilliant, needle-like crystals are slowly formed. At ordinary temperature the reaction will detect one part of nitric acid in 60,000 of water, and it is still more delicate at 0°. Unfortunately, there are other acids which also give precipitates with the reagent, and thus chlorates, perchlorates, bromides, iodides, nitrites, chromates, sulphocyanides, ferro- and ferricyanides, picric acid, and oxalates interfere with the test.

To make the quantitative determination, the substance (containing about 0·1 g. of nitric acid) is dissolved in 80–100^{ccm} of water, ten drops of dilute sulphuric acid are added, the liquid is warmed nearly to boiling and 10–12^{ccm} of the previously mentioned solution of the reagent are added. The vessel is then allowed to stand 1½–2 hours in ice-water, the precipitate is filtered on a Gooch crucible and washed with a minimum quantity of ice-cold water. The precipitate is dried at 110° for three-quarters of an hour, and the calculation is made from the formula $C_{20}H_{16}N_4 \cdot HNO_3$, which contains only about one-sixth of its weight of HNO_3. Numerous test analyses, some of them made in the presence of NaCl, $CuSO_4$, and $AgNO_3$, show excellent results.

It appears probable that this method will find considerable practical application, for heretofore there has been no method for precipitating and weighing nitric acid.—*Berichte*, xxxviii, 861. H. L. W.

3. *The Unity of Thorium.* — Several years ago Baskerville announced that he had obtained fractions of thorium oxide showing varying specific gravities, which led him to believe that thorium was not a simple element; and in 1904 he advanced the view, based chiefly upon atomic weight determinations with different fractions obtained by volatilizing thorium chloride, that thorium contained three elements, berzelium, thorium (new), and carolinium, with atomic weights 212, 220, and 255, respectively.

R. J. Meyer and A. Gumperz have made a critical study of the volatilization of thorium chloride and of the atomic weight determination in such fractions, but they have been unable to find any evidence of the splitting up of our previously accepted thorium. They show that the method of determining the equivalent weight of thorium used by Baskerville was probably entirely unreliable (and was one which Krüss and Nilson, who have done the best work on this atomic weight, were also unable to use). They produced fractions of thorium chloride which should have corresponded to the so-called berzelium, etc., and obtained, by an accurate method of equivalent weight determination, perfectly constant results.

As further evidence of the unity of thorium, G. EBERHARD has made a careful study of the arc spectrum of many samples of thorium material, including fractions made by a process of crystallization by the late Dr. Drossbach, fractions of the chloride by R. J. Meyer, and other preparations from thorite, fergusonite, yttrialite, and uraninite, and he has found no evidence that any separation of thorium into several components has taken place, or has even been begun. He concludes that the results of his observations show that any element different from the old thorium could be present in these samples only in very insignificant quantity.—*Berichte*, xxxviii, 817, 826. H. L. W.

4. *Nitroxyl Chloride.* — According to the results of several investigators, the acid chloride NO_2Cl has been supposed to have been prepared, by the action of chlorine upon NO_2, by the action of chlorine upon silver nitrate, and the reaction of NO_2 with PCl_5. Other investigators have been unable to confirm the existence of this compound, and now GUTBIER and LOHMANN have made an elaborate series of experiments using all the suggested methods of preparation, and they have arrived at the conclusion that this "chloride of nitric acid" has not yet been produced.—*Jour. prakt. Chem.*, lxxi, 182. H. L. W.

5. *The Heusler Magnetic Alloys.*—These alloys consist of manganese, aluminium and copper; which under suitable proportions and conditions of temperature shows a magnetic state comparable with that of cast iron. E. GUMLICH has made a careful study of two specimens of the following constitution:

1. Cu 61·5 per cent, Mn 23·5 per ct, Al 15 per ct, Pb 0·1 per ct.
2. Cu 67·7 " Mn 20·5 " Al 10·7 " Pb 1·2 "

The magnetic measurements were made with cylindrical rods 18^{cm} long and $0{\cdot}6^{cm}$ diameter. Since the molecular conditions under changes of temperature promised to throw the most light upon this remarkable manifestation of magnetism in an aggregation of non-magnetizable metals, Gumlich submitted the alloys to a considerable range of temperature during the magnetic measurements. At the temperature of liquid air no marked change was observed. Considerable changes, however, ensued on raising the temperature of the alloys. With a field strength of $H = 150$ the flux of induction was noticeably greater in alloy 1, which contained the larger proportion of manganese and the smaller proportion of lead. The rods were submitted first to a temperature of 79° in alcohol steam for nine hours, and afterwards to 110° (melting point of toluol) for 27 hours. Rod 1 showed no marked change; but in the case of rod 2 there was a marked change of flux of induction, coercitive force, residual magnetism, and maximum permeability. L. Austin finds that the alloy resembles the magnetic metals in its volume-changes in a strong magnetic field.—*Ann. der Phys.*, No. 3, 1905, pp. 535–550. J. T.

6. *A High Frequency Alternator.*—W. DUDDELL describes an alternator which was primarily used in experiments on the resistance of an electric arc in which the interesting result was

obtained that this resistance with each increase of frequency behaved more like a solid resistance. The alternator was altered until the very high frequency of 120,000 cycles per second was obtained. The alternator was first driven by a figure of eight drive consisting of two bicycle wheels, one fixed direct to the motor shaft as the driving wheel, the other acting as a tension pulley to balance the pull on the alternator spindle. A surprising amount of power was required to drive the bicycle wheel at high speeds even without the inductor, and the author computes that the air friction on a single bicycle wheel running at 1200 revolutions per minute, or at a rim velocity of about 85½ miles per hour, required an expenditure of energy at the rate of about 200 watts; so that a cyclist to attain this speed would have to develop over one-half horse power to overcome the air friction on his wheels alone. The bicycle wheels were replaced by two phosphor-bronze discs, both being made drivers. The author describes his difficulties with belts. A cotton cord three-sixteenths of an inch in diameter gave the best results. In spite of every care all attempts to run the inductor at 1000 revolutions per second failed from the axis of inertia of the inductor not coinciding with its mechanical axis. If these axes were parallel and 1^{mm} apart, the pressure at 1000 revolutions per second on the two bearings would amount to 0·8 metric ton, which would be prohibitive on such small bearings. The inductor consisted of laminated toothed discs of iron which revolved between two pole tips provided with coils. A current of 0·1 ampere was obtained at a frequency of 120,000 per second. As an illustration of this high frequency the author remarks that in plotting curves for ordinary frequencies of 50 to 100 cycles per second the scale often adopted is 10 inches for 100 cycles. If it were attempted to plot a curve up to 120,000 cycles per second the paper would require to be nearly one-fifth of a mile long.—*Phil. Mag.*, March, 1905, pp. 299, 309. J. T.

7. *Deviation during Free Fall.*—It is still a question whether a southerly deviation of a freely falling body has ever been detected. De Sparre asserts that the formulæ usually given for easterly and southerly deviation during free fall are erroneous; for the variation in centrifugal force and the magnitude and direction of the weight are generally neglected. He gives mathematical expressions for the southerly deviation, according as the fall takes place in a well or from a tower. In any case the southerly deviation is too small for measurement, being less than $0{\cdot}1^{mm}$ for a fall of 1^{km}.—*Comptes Rendus*, cxl, Jan., 1905, pp. 33–35. J. T.

8. *Polarized Röntgen Radiation;* by Charles G. Barkla. (Abstract of a paper read before the Royal Society of London, Feb. 16, 1905.)—Experiments on secondary radiation from gases and light solids subject to X-rays showed that the character of this radiation differs only very slightly from that of the radiation producing it, and that the energy of this radiation is proportional

merely to the quantity of matter through which a beam of Röntgen radiation of definite intensity passes, being independent of the kind of matter.

These results, and the agreement between the energy experimentally determined and that calculated, led to the conclusion that this radiation is due to what may be called a scattering of primary X-rays by the corpuscles or electrons constituting the molecules of the substance.

On the hypothesis that Röntgen rays consist of a succession of electro-magnetic pulses in the ether, each electron in the medium through which these pulses pass has its motion accelerated by the intense electric fields in these pulses, and consequently is the origin of a secondary radiation, which is most intense in the direction perpendicular to that of acceleration of the electron, and vanishes in the direction of that acceleration. The direction of electric intensity at a point in a secondary pulse is perpendicular to the line joining this point and the origin of the pulse, and is in the plane passing through the direction of acceleration of the electron.

On this theory, a secondary beam whose direction of propagation is perpendicular to that of the primary, will be plane polarized, the direction of electric intensity being parallel to the pulse-front in the primary beam. If the primary beam be plane polarized, the secondary radiation from the charged corpuscles or electrons has a maximum intensity in a direction perpendicular to that of electric displacement in the primary beam, and zero intensity in the direction of electric displacement.

The secondary radiation from light substances was too feeble to allow accurate measurement of the intensity of the tertiary radiation.

A consideration of the method of production of primary Röntgen rays in an X-ray tube, however, leads one to expect partial polarization of the primary beam proceeding from the anti-cathode in a direction perpendicular to that of propagation of the impinging cathode rays, for there is probably at the anti-cathode a greater acceleration along the line of propagation of the cathode rays than in a direction at right angles; consequently in a beam of X-rays proceeding in a direction perpendicular to that of the cathode stream there should be greater electric intensity parallel to the stream than in a direction at right angles.

Such a beam was therefore used as the primary radiation, and the intensity of secondary radiation proceeding in a direction perpendicular to that of propagation of the primary beam from a radiator placed in that beam, was studied by means of electroscopes.

In the final form of apparatus the intensity of secondary radiation was measured in two directions perpendicular to that of propagation of the primary radiation and to each other, while the intensity of the primary beam was measured by a third electroscope.

Using paper, aluminium, or air as the radiator, as the bulb was turned round the axis of the primary beam studied, the intensity of a secondary beam was found to reach a maximum when the direction of the cathode stream was perpendicular to that of propagation of the secondary beam, and a minimum when these two were parallel, one electroscope recording a maximum rate of deflection when the other recorded a minimum. Many experiments were made which proved the evidence of partial polarization conclusive.

When heavier metals, such as copper, tin, and lead, which emit a secondary radiation differing considerably in character from the primary producing it, were used as radiators, no variation in intensity of secondary radiation was observed as the bulb was rotated. This result was not found to be affected by a considerable variation in the penetrating power of the primary radiation.

Experiments were made with several X-ray tubes.—*Proc. Roy. Soc.*, lxxiv, 474.

II. Geology and Mineralogy.

1. *Plans for Obtaining Subterranean Temperatures.* — The recently issued Year Book, No. 3 of the Carnegie Institution of Washington, contains a report by G. K. Gilbert of the progress made in developing plans for an investigation of the subterranean temperature-gradient by means of a deep boring in plutonic rock. Mr. Gilbert discusses in detail the importance of such an investigation and the conditions that should be satisfied in the solution of the place for the boring. The conclusion is reached that an altogether favorable locality for the work is to be found in the Lithonia granite district in Georgia. In regard to this region in its applicability to the object in view, the author says :

"In its general topographic character the Lithonia district is a plain. The stream valleys, for the most part open, are excavated to depths of 50 to 150 feet. A few rounded bosses of granite project from 50 to 150 feet above the plain. The granite is surrounded and in part overlain by schists, which appear to have originally constituted the walls and cover of the batholithic chamber. The continuity of the granite mass from outcrop to outcrop is inferred from the close lithologic similarity found at all the outcrops. This similarity includes not only composition, but a peculiar and unusual structure, the granite having an imperfect schistosity, the planes of which are everywhere contorted. It is therefore called by the State Geological Survey *contorted granite-gneiss.* The rock is massive. Only a few joints were observed, and these appeared to be occupied by thin veins, and thereby sealed, so as not to affect materially the continuity of the rock. The partings utilized in quarrying are parallel to the surface and are usually not natural, but created by blasting. They indicate a tendency toward exfoliation, which is one of the characters of massive granite. In recent studies in the Sierra Nevada I have found the tendency to develop partings parallel to the

surface characteristic of massive rocks and absent from rocks traversed by systems of joints.

The extent of the granite body is not less than 10 miles in one direction by 3 miles or more in the transverse direction. Uniformity of character through such an area affords reasonable presumption that uniformity will be found in the vertical direction to such depths as are obtainable by the driller. The age of the batholith is not definitely known, but it is believed by students of Georgia geology to be probably pre-Paleozoic, and certainly not later than early Paleozoic. Of the later geologic history all that is demonstrated by the features of the locality is profound degradation, resulting in the development of a broad peneplain. Nothing is known in the vicinity of later orogenic or volcanic events, and the Cretaceous and Tertiary formations of the Coastal Plain are thought not to have covered this area. So far as is known, the region is one characterized by prolonged geologic quiet, and it has probably been exempt, as far as any locality which might have been selected in the United States, from physical and climatic accidents competent to disturb the arrangement of subterranean temperatures."

Besides the actual determination of the temperature-gradient, the conditions will be favorable for the prosecution of other investigations. The study of the core obtained would give valuable data as to the strength and physical properties of deeply buried granite. Further:

"It is at least worthy of suggestion that the boring could also be utilized for the subterranean swinging of a specially constructed pendulum, and the measurement of the earth's weight by means of a vertical pair of gravity determinations could thus be repeated. The homogeneity of the crust layer between the upper and lower stations and the representative character of the rock samples brought up as drill cores would be peculiarly favorable for the determination of the density of the crust layer.

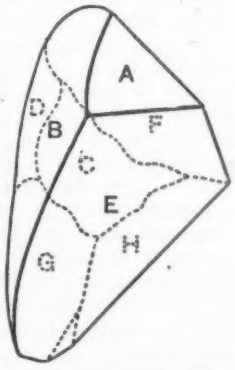
To give high precision to the determination of density it would be necessary to take account of the compression of the rock under stress of the superincumbent weight. Rock compression has not yet been measured in the laboratory, the matter being one of extreme difficulty, by reason of the deformation of both samples and testing apparatus when great pressures are applied; but there is reason to think that valuable observations bearing on this point could be made within the boring at some stage of the work. It should be possible, by suitable automatic appliances, to measure that resilient elongation of the column of rock constituting a section of core which theoretically takes place while the drill is separating it from the general mass. The importance to geophysics of experimental determinations of rock compression is generally recognized."

It is much to be hoped that it may prove possible to go forward with this most important investigation. The expense would be large, of course, but for a depth of 6000 feet not prohibitory; one estimate puts the cost of the boring at $110,000.

2. *Vermont Geological Survey;* G. H. PERKINS, State Geologist. Annual Report, 1903–1904, 227 pp., 8 figs., 81 pls.—The fourth of the present series of Vermont State Reports indicates great activity on the part of Professor Perkins and his co-workers. In addition to a description of the present condition of quarry industries within the state, the report contains articles by Professor C. H. Hitchcock on the Glaciation of the Green Mountain Range, Professor V. F. Marsters on the Asbestos Deposits, and a paper by the state geologist on the Geology of Grand Isle County and the Brandon Lignite Deposit. Grand Isle County has been completely mapped in the past two years and the fossils have been studied. A special paper on the Stromatoceria of Isle LaMotte has been written by Professor H. M. Seeley. The origin of serpentine is discussed somewhat by Professor Marsters, who believes that magnetite may be shown to pass by imperceptible stages of decomposition into masses of fibrous serpentine. The interesting Tertiary deposits at Brandon are described and seven plates illustrating the fossil forms are published.

3. *The big "Cullinan" Diamond from the Transvaal.*—The April number of the Geological Magazine contains a description by F. H. HATCH and G. S. CORSTORPHINE of the large diamond recently found in the Transvaal; from this we quote the following paragraphs. Two plates with four excellent views of the stone, natural size, accompany the paper but cannot be reproduced here.

"Great interest has been excited, not only in the Transvaal, but throughout the world, by the discovery at the Premier Mine, on Wednesday, the 25th January, 1905, of the largest diamond hitherto known. The stone was found by Mr. Wells, Surface Manager, in the yellow ground about 18 feet from the surface, a brilliant flash of light from a projecting corner having caught his attention. After a preliminary cleaning it weighs 3,024¾ carats. According to Gardner Williams the South African carat is equivalent to 3·174 grains; consequently the diamond weighs 9600·5 grains troy or 1·37 lbs. avoirdupois. Through the courtesy of the Directors of the Company, we have been enabled to make an examination of the stone, with the following result: It measures 4 by 2½ by 2 inches. The stone is bounded by eight surfaces, four of which are faces of the original crystal, and will be referred to in this description under the letters A, B, C, D, and four are cleavage surfaces, the cleavage being of course parallel to the face of the octahedron. In the following description these cleavage surfaces are referred to under the let-



Diagrammatic projection (to half scale).

ters E, F, G, H. They are distinguished from the original octahedral faces by greater regularity and smoothness. The shape and relative position of these various surfaces can be seen in the diagrammatic projection depicted in the text-figure, which has been drawn in the Mineralogical Laboratory of the Oxford University Museum, by the kind permission of Prof. Miers, F.R.S. The drawing is to half scale.

Description of the Surfaces.—A is an original octahedral face showing typical striations, the bands varying from 0·1 to 0·4 centimeter, and running parallel to the edge A–E. B is a large surface slightly curved showing partial striations, which, however, are interrupted by the slightly mammillary character of the surface. C is also a natural surface showing a few striations parallel to the edge C–E. D. Between B and F, C, G, there is an irregular octahedral face D, showing distinct equilateral triangular indentations which resemble etched figures, except in regard to their comparatively large size, the largest having a side measuring 0·7 centimeter. D is parallel to E.

E, F, G, H, are cleavage planes. E is the largest of these, and is a very perfect cleavage plane. Parallel to it within the crystal there is a small air layer between two internal cleavages, producing a 'rainbow' or Newton's rings. F is the second largest of the cleavage planes and shows a small spot within the crystal. G is an irregularly shaped cleavage plane. H is another cleavage face showing series of cleavages in the corner bounded by E and G. Two spots are visible, one actually on the surface, the other about 1^{cm} within the crystal. Of the faces given, A and G, H and B, and E and D are parallel. In the case of B and H the parallelism is imperfect owing to the curvature of B.

The purity of the crystal is best seen on looking into face E, and the luster is well seen on the irregular natural face B, the broken cleavage on H causing a good deal of refraction which affects B to some extent as the facets of a cut gem would. For a large stone the crystal is of remarkable purity, and the color approximates to that of a blue-white.

The large size of the cleavage planes E and F indicates that a very considerable portion of the crystal is wanting. From the shape of B, D, and G, one can say that the entire crystal was irregular in shape, but A and D being octahedral faces, the presumption is that the complete crystal was a distorted octahedron, probably with dodecahedral faces developed on the edges. The portions missing probably amount to more than half of the original crystal.

The Cullinan diamond, as it has been named, after the chairman of the Premier Company, is more than three times the weight of the largest diamond previously known—the famous stone found in 1893 at Jagersfontein in the Orange River Colony, which weighed 972 carats.

4. *Moissanite, a Natural Silicon Carbide;* by GEORGE FREDERICK KUNZ.*—Professor Henri Moissan, at a meeting of the

*Read before the New York Academy of Sciences, Jan. 9, 1905.

Academy of Sciences of Paris, held November 14th, 1904, read a paper on an examination made by him of a block of meteoric iron from Canyon Diablo, Arizona, which weighed 183 kilograms (403·6 lbs.).* Professor Moissan determined this mass to be somewhat heterogeneous in its structure, and to contain iron, nickel, sulphur, phosphorus, silicon and carbon. He found the latter element in its several forms,—amorphous carbon, graphite, and diamond,—and was able to separate both the black and the transparent variety of the diamond. He also discovered as absolutely new, in connection with these, green hexagonal crystals of silicon carbide. This is the substance which has been so extensively manufactured and sold commercially under the name of *carborundum*, and which, having a hardness of 9·5, above that of all minerals except the diamond, forms an admirable abrasive material for sawing gems, engraving glass, etc.

As this is the first instance in which this compound has been proved to occur in nature, and therefore, as a mineral, is entitled to a distinct mineralogical name, it would seem that the name of Professor Moissan himself should be associated with it. I would, therefore, propose for it the name of *Moissanite*, as a slight recognition of his many services to chemistry, and especially of his researches on the artificial carbides and his study of the constituents of meteorites, and the reproduction of similar substances by means of the electric furnace.

Photographs made by Professor Moissan show that the specimens isolated were entire crystals and must have been formed in the meteoric mass itself; they were not fragments such as were found by an American investigator a few years ago associated with fragments of corundum, which upon a careful search of the material he learned had been ground into the meteoric mass from the abrasive used in sawing the meteorite. No saws were used by Professor Moissan with the mass examined by him.

5. *Occurrence of Palladium and Platinum in Brazil.* — A very full and interesting paper upon this subject is given by E. Hussak in vol. cxiii of the Sitzungsberichte of the Vienna Academy (Abth. I). An exhaustive summary of the historical data is followed by an account of the author's own extended observations.

The metal *palladium*, in the native state, was discovered by Wollaston in Brazil a hundred years ago, being identified with native platinum in sands from gold washings, probably at Conceicao. The author failed to find the metal in the platinum sands of this locality, but he proved that it did occur in irregular grains (not rolled) of dark gray to steel-gray color with platinum and palladium-gold in the highly auriferous "Jacutinga"† of the itabirites of Itabira do Matto Dentro, Minas Geraes.

* Comptes Rendus, cxxxix, No. 20, cxl, No. 5, p. 277; also Chem. News, Dec. 14, 1904, Feb. 24, 1905; this Journal, xix, 191, 323, 1905.

† The name "Jacutinga" is given to the narrow layers and bands, hardly 50cm in thickness, that occur interbedded conformably within the itabirite (a quartz-hematite rock of schistose structure). The Jacutinga are often enormously rich in gold, which may be nearly absent from the surrounding itabirite.

Palladium-gold, an alloy of the two metals in varying proportions, is not uncommon and the scales of "white gold" belonging here were noted as early as 1700 though at first supposed to be silver.

It occurs in the gold washings at various points in the states Goyaz and Minas Geraes. It is also found, with native platinum in the rock itself, thus in the "Jacutinga" at the Gongo Socco mine near Caethe Minas, at Itabira do Matto Dentro and at Maquine near Villa Marianna. It also occurs at Candonga, Minas Geraes, in a pyroxene rock which is probably derived from a limestone by contact metamorphism. This rock forms layers in the itabirite.

Platinum has been known to exist in Brazil for about one hundred years, but, previous to the identification of palladium, it was often confounded with the alloy palladium-gold. The explorations and investigations of the past thirty years have added largely to the number of localities of native platinum, which may be summarized as follows:

(*a*) It occurs sparsely disseminated through the highly auriferous Jacutinga, interbedded in the itabirite, as at Gongo Socco.

(*b*) In the auriferous quartz veins of the crystalline schists on the Rio Bruscus, Pernambuco.

(*c*) Associated with the less frequent diamond and probably derived from quartz conglomerates, on the east slopes of the Serra do Espinhaco from Itambe do Matto Dentro to Itambe do Serro.

(*d*) In the Rio Abaete and its left tributaries, here probably derived from olivine-rocks as in the Urals.

It is noteworthy that the platinum of occurrences (*c*) and (*d*) varies widely in composition; that of Conceicao is non-magnetic and free from palladium with a specific gravity of 20·5; that from Condado is non-magnetic and rich in palladium, and that of Abaete is strongly magnetic and free from palladium, but rich in iron. The specific gravity of the platinum from Condado is from 15 to 15·5. The specific gravity of the metal from Abaete could not be determined because it was impossible to obtain the fine powder free from gold and perovskite.

In the occurrences (*a*), (*b*) and (*d*) the platinum seems to be a primary constituent, but in the remaining case, where it accompanies the diamond, it has so peculiar a form that a secondary formation is thought probable. Here the platinum appears not as rolled grains but in hollow forms, sometimes fern-shaped, with thin walls and mammillary or botryoidal, non-crystalline, surface; the structure is both concentric and fibrous. These forms are so unusual that a possible secondary origin is suggested, perhaps a deposit from solutions derived from the decomposition of sulphides carrying platinum. Such a formation the author regards as quite possible, since in the United States and Norway, ores of this kind (pyrrhotite, covellite, chalcopyrite) have been shown to carry platinum and to be associated with sperrylite ($PtAs_2$).

6. *Platinum Resources in the United States.* — The Geological Survey has undertaken the investigation of the resources of plati-

num in the country, having issued a circular giving information as to the nature and occurrence of the metal, and instructions as to sending samples, especially of heavy sands from placer mines, to Washington for thorough examination. A list is also given of the various localities, chiefly in California, Oregon, Canada and South America, in which platinum has been discovered, with indications as to which regions offer the most promise. It is to be hoped that this effort will result in developing the supply of the metal which is so much needed.

7. *Beiträge zur Mineralogie von Japan;* herausgegeben von T. WADA. No. 1. Pp. 1–21. Tokio, 1905.—The recently issued volume on "The Minerals of Japan" by T. Wada was noticed in the January number. The same author has also undertaken the publication of a series of contributions to the mineralogy of Japan, of which the first number is now in hand. This contains an interesting account by Kotora Jimbo of crystals of *danburite* of Obira, Bungo Province, with list of forms observed and angles measured. Another paper by the same author describes the *siliceous oolite* of Tateyama, Etchū Province. This oolite either consists of loose colorless spherules of opaline silica or forms a loosely coherent mass of colorless or gray spherules cemented by partly anisotropic colorless opal, or opal mixed with decomposed rock particles; the spherules are also found in loose form. Microscopic examination shows a concentric structure with a series of rings. These rings are in part nearly structureless and isotropic, in part fibrous and doubly refractive; the fibers are negative; between crossed nicols a black cross is obtained. The hardness of the spherules is about 6, the specific gravity nearly 2. They contain 93 per cent SiO_2 and about 4 per cent loss on ignition. After ignition more than 80 per cent of the powder is dissolved in four hours in KHO with eight parts of water.

The deposit described occurs in connection with the small crater-lake of Shin-yu, 70 miles in diameter, and not far from the well-known hot springs of Tateyama. The lake is now filled with hot, gray, turbid water, from which abundant gas-bubbles issue; formerly the water is stated to have been cold.

The occurrence is one of much interest, since, as remarked by the author, it is the modern equivalent of the ancient springs of Pennsylvania described by various authors, among them Barbour and Torrey, see this Journal, xl, 246, 1890, also Wieland, ibid., iv, 262, 1897; the latest investigation is by Diller, Bull. U. S. G. Surv. 150, p. 95, 1900. The spherules of Tateyama differ from those of Pennsylvania in their lower specific gravity, their less crystalline appearance and greater solubility in caustic potash.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The spring meeting of the National Academy was held at Washington, April 18 to 20.

Five new members were elected at the meeting: Arthur A. Noyes, Boston, Mass.; Michael I. Pupin, New York City; John

C. Branner, Stanford University, Cal.; William H. Holmes, Washington, D. C.; William H. Howell, Baltimore, Md.

The following foreign associates were also elected: M. Henri Becquerel, of Paris, and Prof. Dr. Paul Groth, of Munich.

The list of papers presented is as follows:

EDWARD L. NICHOLS: The mechanical equivalent of light.

Dr. H. C. WOOD and Dr. DANIEL M. HOYT: The effects of alcohol upon the circulation.

ALEXANDER AGASSIZ: The expedition of the U. S. Fish Commission Steamer "Albatross," in charge of Alexander Agassiz, in the Eastern Pacific, Lieut. Commander L. M. Garrett commanding.

WILLIAM M. DAVIS: Resequent valleys. The geographical cycle in an arid climate.

W. W. CAMPBELL: A catalogue of spectroscopic binary stars.

C. D. PERRINE: Discovery of the sixth and seventh satellites of Jupiter and their preliminary orbits.

W. K. BROOKS: The axis of symmetry of the ovaria egg of the oyster.

2. *Astronomical Observatory of Harvard College.* — Recent publications include the following:

ANNALS. Vol. LVI, No. II, Stars having Spectra of Class B.

Vol. LVIII, Part I. Observations and investigations made at the Blue Hill Meteorological Observatory, Massachusetts, under the direction of A. Lawrence Rotch. This part, of 62 pages, is devoted to a discussion by H. HELM CLAYTON of the diurnal and annual periods of temperature, humidity and wind-velocity up to 4 kilometers in the free air and the average vertical gradients of these elements at Blue Hill. Among other points of interest, it is shown that there is a rapid increase in wind-velocity from the ground to 500 meters, the rate being about twice as great in the night as in the day. From 500 up to 1000 meters, there is a slow increase in wind-velocity during the day but, in the average, a decrease by night. Above 1000 meters there is a steady increase of wind-velocity and the rate grows larger with increasing height.

CIRCULARS: No. 86, The nebula of Orion. No. 87, The ninth satellite of Saturn. No. 88, A new Algol variable $-15°$ 4905. No. 89, The November Meteors of 1904. No. 90, 105 new variable stars in Scorpius. No. 91, 16 new variable stars in Sagittarius. No. 92, Stars having peculiar spectra.

3. *The Journal of Agricultural Science;* edited by R. H. Biffen, A. D. Hall, T. H. Middleton, T. B. Wood, in consultation with W. Bateson, J. R. Campbell, W. Somerville. Vol. I, Part I, pp. 1–148. January, 1905. Cambridge (The University Press). —This new journal has been recently started to give an organ for the presentation and discussion of scientific papers bearing on agriculture. It is proposed to issue the Journal as material accumulates, in parts of about 100 royal 8vo pages; a volume will contain four parts. Subscription ($4.50, single numbers $1.50) may be made to the Macmillan Co., New York City.

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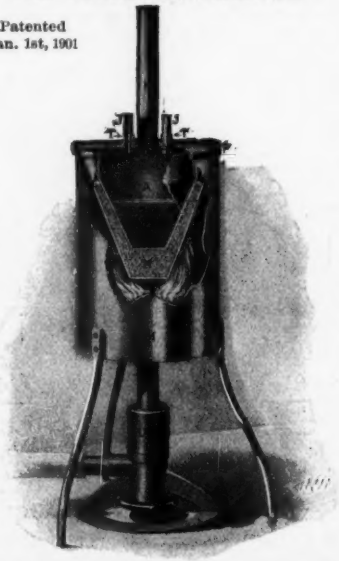

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